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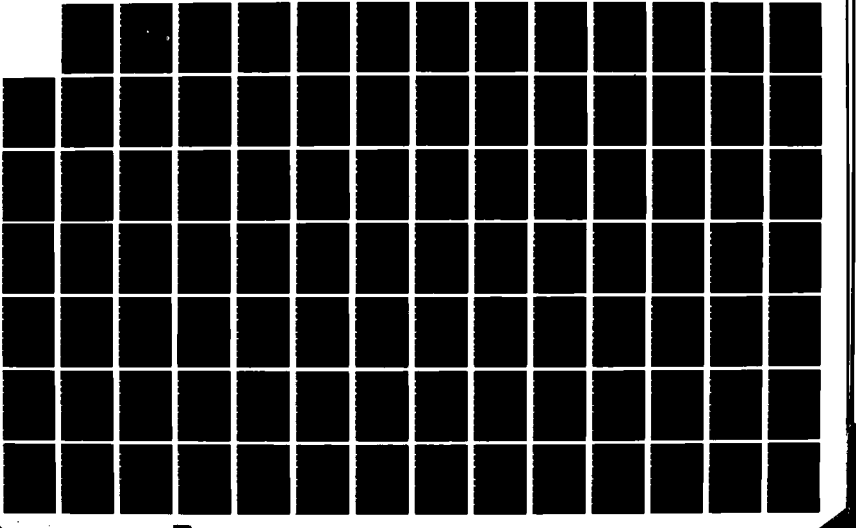

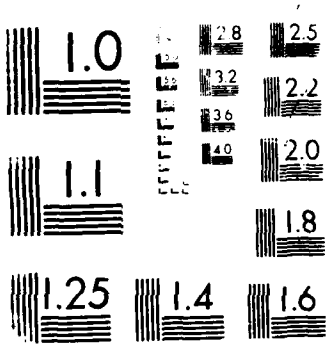
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NAVAL POSTGRADUATE SCHOOL

Monterey, California

THESIS

A PERSONNEL FLOW MODEL FOR PREDICTING THE COAST GUARD ENLISTED FORCE STRUCTURE

by

Lance L. Bardo

September 1987

Thesis Advisor: Paul R. Milch

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The U. S. Coast Guard is a military service with a hierarchical organization. CG manpower planning requires a forecast of the number of accessions needed as well as the resulting force structure for each month of the upcoming year. In this thesis, we present a modified Markov transition model that integrates the pertinent personnel flows to forecast the monthly accessions and force structure for the enlisted CG. Personnel flows are estimated using standard statistical techniques such as linear regression analysis and point estimation. An algorithm is presented to solve for end of month stocks while meeting a man year consumption constraint--Full Time Equivalent (FTE) when attrition rates and the beginning and end of year stocks are given. Finally, the pertinent personnel flow estimates, the FTE algorithm and the modified Markov model are integrated into a comprehensive Military Employment Capability Plan which is programmed on a micro-computer spreadsheet.

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A Personnel Flow Model for Predicting the Coast Guard Enlisted Force Structure

by

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Submitted in partial fulfillment of the requirements for the degree of

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ABSTRACT

The U. S. Coast Guard is a military service with a hierarchical organization. CG manpower planning requires a forecast of the number of accessions needed as well as the resulting force structure for each month of the upcoming year. In this thesis, we present a modified Markov transition model that integrates the pertinent personnel flows to forecast the monthly accessions and force structure for the enlisted CG. Personnel flows are estimated using standard statistical techniques such as linear regression analysis and point estimation. An algorithm is presented to solve for end of month stocks while meeting a man year consumption constraint--Full Time Equivalent (FTE) when attrition rates and the beginning and end of year stocks are given. Finally, the pertinent personnel flow estimates, the FTE algorithm and the modified Markov model are integrated into a comprehensive Military Employment Capability Plan which is programmed on a micro-computer spreadsheet.

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I. INTRODUCTION

The Coast Guard (CG) is a military service with a clearly defined hierarchical organization. It is important to the service and the taxpayer to maintain an adequate force structure efficiently and economically. An important element in manpower planning is to forecast the number of accessions needed each year to replace attritions and to meet changes in total force size. Additionally, budgetary planning requires force structure projections to anticipate payroll costs. Approximately fifty percent of the Coast Guard's annual budget is related to payroll costs which are highly correlated to the number of people at each grade level.

A variety of internal and external factors impact on attempts to forecast future accessions and force structure. Previous recruit projections had the benefit of a relatively large pool of eligible entry level personnel and a stable force size. This allowed the Coast Guard to maintain high standards in recruit quality and waiting lists of enlistees above the monthly recruit quotas. A national shrinkage of eligible entry level personnel described by Fernandez [Ref. 1], stable economic conditions and anticipated changes in the force size require relatively accurate forecasts of accession needs which reflect the impact of the most significant internal and external factors.

The Enlisted Programs Branch of the Office of Personnel, U. S. Coast Guard is responsible for projecting the Coast Guard's enlisted accession needs and the enlisted force structure for each month of the upcoming fiscal year.

A. OBJECTIVES

The objective of this study is to formulate a mathematical model which projects the enlisted accession needs and enlisted force structure on a monthly basis for the next fiscal year. The model should also be able to take current data during a fiscal year and adjust the projections for the remainder of the fiscal year. We will implement the model in a commercial spreadsheet environment compatible with the background of the intended CG users. We anticipate this will also provide maximum flexibility to explore the effect of a number of variations in external conditions and internal policies impacting the forecasts.

B. BACKGROUND

The Coast Guard operates under the Department of Transportation. The enlisted force structure is hierarchical with paygrades E-1 to E-9, lowest to highest respectively. (There is a paygrade E-10 which has a size of one and will be ignored in this study.) Each paygrade is further broken down into approximately 25 sub-specialties (ratings).

Promotions occur on the first of the month only. The CG conducts semi-annual testing of personnel to rank order

personnel eligible for advancement to paygrades E-5 to E-9. These promotions are vacancy driven. Promotion to paygrades E-3 and E-4 occurs on qualification for advancement. Promotion to paygrade E-2 occurs upon completion of recruit training. Vacancies are determined by the difference between actual stocks and the authorized structure as promulgated periodically during the year by the Chief of Staff's Personnel Allowance Branch. There is a statutory upper limit for E-9s and E-8s (one and two percent of the total enlisted force size respectively). If the number of personnel eligible for promotion (defined as having passed the servicewide examination) in paygrades E-5 through E-9 exceeds the vacancies occurring during the period, those personnel eligible for promotion may recompete for promotion during the next servicewide examination. Normally, once an enlisted person meets the requirements for promotion, he remains eligible for promotion indefinitely (i.e. there is not a promotion zone for enlisted personnel like there is for officers).

Accessions may theoretically occur in all paygrades. First time enlistees are entered as E-1s. Prior service enlistees and CG personnel reenlisting more than 24 hours after the expiration of their previous contract are entered in paygrades E-2 to E-7, depending on previous service experience and the needs of the service (needs of the service are directly tied to the Selective Reenlistment Program).

Additional accessions in all paygrades occur when reservists are entered into extended active duty.

Attritions occur in six general categories:

1. Retirements

   Retirements normally on the first of the month.

2. Non-Reenlistments

   A CG member may not chose or may not be eligible to reenlist or extend his/her contract at expiration.

3. Administrative

   A member may be discharged prior to the expiration of his enlistment for the "convenience of the government".

4. Death

5. Reservists on extended active duty

   Reservists may be released back to inactive reserve status.

6. Officer Programs

   An enlisted member may be selected for an officer program (Warrant Officer, the Academy, or Officer Candidate School).

The Enlisted Programs branch currently uses a model called the Military Employment Capability Plan (MECP) to project accession needs and force structure. A replacement for this model is desired that will integrate pertinent external influences and accurately reflect the effect of internal policy changes such as a changed promotion policy.

The MECP model and its output is used by a variety of people with a wide range of mathematical sophistication . It is essential for the model to remain uncomplicated , comprehensible and easily maintainable.

C. MODEL FORMULATION APPROACH

The model proposed in this study is a modified Markov transition model that makes use of historical internal CG personnel data and historical external data (various economic indicators) . The Markov model is constrained by internally and externally (statutory) imposed policies. It is predictive in nature. The model will forecast future strengths across paygrades for the coming months of the year.

Our model and solution will be developed as follows:

1. In Chapter II we examine the data available to seek obvious interrelationships, trends or data anomalies.

2. In Chapter III, we develop an appropriate predictive model for the personnel transition rates and attritions.

3. In Chapter IV, we formulate and solve an algorithm for the manyear consumption constraint (Full Time Equivalent).

4. In Chapter V, we implement an appropriate Markov Transition model.

5. In Chapter VI, we summarize the operational limitations of the model and discuss applications of the model in response to a number of hypothetical conditions.

6. In Chapter VII, we validate the model and summarize the results .

II. DATA ANALYSIS

The data used in this thesis can be divided into two general categories--internal CG personnel data obtained from various databases and reports and external economic data collected from readily available publications .

A. ENDOGENOUS DATA COLLECTION

Most of the data obtained from the CG personnel system came either directly or indirectly from the Personnel Management Information System (PMIS) maintained on the DOT Amdahl computer located at the DOT building in Washington, DC. PMIS is the master database of CG personnel data and is the basis of all pay, time in service, and all other personnel calculations for the CG. Queries of the database were conducted with two commercial software packages--SAS and FOCUS. Data also came from other databases or files which are kept by individual CG offices. Three problems arose in the collection of this data. First, obvious errors in data entry were observed, as there appears to be limited data entry validation within the PMIS data base. Second, historic PMIS data is essentially purged at the end of a fiscal year of all data not related to current personnel. This means that raw historic data is destroyed for personnel who have left the service during the preceding fiscal year. Data is also lost for some of the transactions related to

current personnel. Complete historic data for preceding fiscal years is either lost or only available in the formats and categorical breakdown of standard printed reports issued by the system and kept on record in various CG offices. Some information regarding separations (attritions) is downloaded to magnetic tape for future reference. Thirdly, when other data sources are used, it appears that the effective dates of certain personnel actions (separations, promotions,etc) may differ from data source to data source. This problem is important to consider when cross validating data between sources or when trying to derive missing data based on the conservation of flow principle [Ref. 2:pp. 4-6]:

$$\text{Stock}_i(t+1) = \text{Stock}_i(t) + \text{accessions}_i(t) + \text{promotions}_{i-1,i}(t) - \text{attritions}_i(t) - \text{promotions}_{i,i+1}(t) \qquad [2.1]$$

$$i = \text{paygrade } 1,2,\ldots,9$$

These problems limited the collection of a complete set of usable data to four fiscal years (1983 - 1986). We also collected data for the first eight months of FY87 to use in model validation.

Lastly, the data we collected was further categorized by specialty (rating). We decided early in the analysis to combine these categories into a simple total for each paygrade because the output required from this analysis is not to be categorized by rating. An initial look at the data also indicated that further categorization into ratings would reduce the data collected in each cell to such a small size

as to introduce significant difficulties in conducting a reliable statistical analysis.

1. Stocks

We obtained the stocks of the CG personnel from the PMIS generated Comparative Status report (COMSTAT). This data was separated by month, paygrade and rating. We aggregated over ratings to obtain data by month and paygrade. E-2 and E-3 stocks include both rated and non-rated personnel. Stocks are as of the last day of the month.

2. Demotions

We obtained demotion data directly from the 1986 PMIS data by month and paygrade . No data was available for prior years. Based on this data and a priori knowledge of the CG, we decided that demotions were statistically insignificant for purposes of this model and could be ignored, as the demotion rate was less than .0001 for any given paygrade and month.

3. Promotions

We obtained this data from the Enlisted Programs Office (derived from the servicewide advancement lists). Data was only available for those paygrades to which promotions are based on the Servicewide competition (E-5 to E-9). Promotion to E-4 occurs upon completion of a specialty school (A-school) and other qualifications and this data was not available. No data was available for promotions to E-2 or E-3. We derived historic promotions to paygrades E-2,

E-3, and E-4 by solving conservation of flow equation [2.1]. We were able to compare the derivation for promotions to E-4 with 1985-86 data available for A-school graduates and personnel promoted through the "striker" program (this process is described in Chapter III) . There was a favorable comparison between the derivations and the data, i.e. the derivations were within ten percent of the data ; time trends and seasonal variations were preserved. We could not use the actual data for 85-86 because the A-school graduate data included an unknown number of personnel who successfully completed A-school but did not complete the other requirements for advancement to E-4. We compared our derivation for promotion to E-2 with data extracted from a 1985 list of recruit training center graduates . We were able to extract approximately 500 usable records from 1000 examined (1/8 of the total). A proportionate comparison of our derivations for the same period indicate the cumulative total of the derivations was within one percent of the extracted data. No data of any form was available to compare with derived promotions to E-3.

The number of promotions for each paygrade and month was divided by the stocks at the beginning of that month to obtain a promotion rate. We considered the desirability of further categorizing the number of personnel in a paygrade by eligibility for promotion, but data was not available to support this effort even though it could have led to a more

accurate calculation of the promotion rate. The reader should bear this in mind when comparing our promotion rates (promotions ÷ stocks) to the usual definition of promotion rates (promotions ÷ number eligible for promotion).

4. Attritions

Attrition data was obtained from a separations tape which is created annually from the PMIS database. Complete information was available for 1981 and 1983-86. The attritions were categorized by paygrade, month and type of attrition (also listed here by PMIS code). The types of attritions (discussed in the introduction) were reservists released from active duty (DA), deaths (AD), retirements(BA), administrative discharges (AF), and non-reenlistments (AA, AB, AC, AE, AF, DA, DB, DC). We originally separated the attritions into categories with the intention of exploring the possibility of obtaining additional information for our predictions based on intuitive knowledge of correlations between attrition type and paygrade (e.g.: 99 percent of E-9 attritions are due to retirements). The data provided numerous confirmations of these type of relationships but ultimately it was determined that no significant improvement to the model could be obtained from this information. We decided to use the total attritions categorized by paygrade and month.

An examination of the data revealed a glaring problem with data from October, November and December 1983

(FY84). The data showed no attritions for October and November and then a unusually large number for December (approximately three times larger than normal). This data anomaly was due to a software conversion. We decided to adjust this data based on other data that we had from the CG report "Enlisted Active Duty Accessions and Attritions", referred to as "36f". This report summarizes attritions for the month by the same types of attritions but does not categorize attritions by paygrade. We felt that by applying the proportions of attritions captured in the "36f" report for these 3 months, we could get a reasonable approximation of the missing data. We were further encouraged in this approximation by the previously discussed analysis which showed that certain types of attritions were closely tied to certain paygrades. For example, we previously determined that almost all attritions in the E-9 paygrade were due to retirements. The "36f" report lists the aggregate number of retirements in a month. We were able to calculate from this data the proportion of total retirements that occurred in each of the three months (OCT, NOV, DEC). We applied this proportion to the original attrition data categorized by paygrade (E-9 in this case). Similar adjustments to the data were calculated based on our previous analysis of correlation between attrition type and paygrade. After the approximation we tested our results with conservation of flow equation [2.1] for the three months for paygrades E-5 through E-9 (as

previously discussed, E-2 through E-4 values of promotions were derived). There were no glaring inconsistencies in the results (all approximations were within two percent of the conservation of flow results and no negative flows were generated).

Two adjustments were made to the data to reflect policy changes that we felt were significant enough to warrant manipulating the data prior to analysis and modelling. The CG instituted a program from March 1986 to July 1986 that allowed a limited number of personnel to voluntarily leave the service prior to the end of their enlistment. The number of people attriting under this program was closely monitored and data was available by paygrade and month reflecting the number of people discharged under this temporary policy. The attritions were subtracted from the total attritions by paygrade and month under the assumption that the discharges would not have occurred without this policy change. Secondly, a number of policy changes at the CG recruit training center have resulted in a significant reduction in E-1 attritions from 1 October 86 through 31 March 87. An analysis of the policy changes indicate that we can reasonably expect this reduction in E-1 attritions to continue. The reduction in attritions over the six months was 35 percent. We reduced the 1983 through 1986 E-1 attritions by this percentage .

The attritions were converted to a monthly attrition rate for each paygrade by dividing the respective number of attritions for a month by the corresponding stocks at the beginning of that month. The monthly aggregate attrition rate was obtained by using the aggregate attritions and stocks.

5. Recruits

Recruit data was obtained from annual summary reports kept by the Office of Military Recruiting (PMR). Recruit data was available for 1980- 1986 by month and paygrade (recruits in paygrade E-1 are raw recruits, those in paygrade E-3 are usually prior service CG, those in paygrade E-2 are usually personnel who have completed enlistments in DOD services, and those in paygrades E-4 to E-7 are prior service personnel with specialty skills in "open ratings". Open ratings and paygrades are defined by the Open Rating List and are tied directly to the Selective Reenlistment Bonus program. The only inputs not included here were reservists coming on active duty. These numbers were derived from conservation of flow equations already described. The other option we considered was to delete the attritions due to reservists returning to inactive duty and make the assumption that the numbers of reservists beginning extended active duty and of reservists ending extended active duty are in equilibrium, which is the assumption currently made by Enlisted Programs branch. An initial examination of the data indicated that this assumption would degrade the quality of the predictions

from this model. Data was also collected for the monthly recruiting quotas set by the Enlisted Programs division and the Military Recruiting branch at the beginning of each fiscal year. Monthly recruiting quotas are the forecasts of monthly accessions that will enable the CG to meet the desired end of month strengths. A comparison of the quotas and the actual accessions can give a historic depiction of the rate of recruiting success during various months of the year by the field recruiters.

6. Expiration of Enlistments

We were able to obtain anticipated expirations of enlistments categorized by month and type (non-rates, first enlistment, subsequent enlistments). This data is obtained from the PMIS database at the beginning of each fiscal year and is the number of enlistment contracts or contract extensions that will expire in the next year.

7. Billets

The Personnel Allowances Division determines the authorized number of personnel in each paygrade. These authorized positions are called billets. Billets minus stocks yield vacancies that can be filled by promotions or accessions. A detailed description of the process surrounding changes to the authorized billets and their use in the manpower flow process is included in Chapter III.

8. Data

Appendices A and B contain the data used .

B. EXOGENOUS DATA

Economic variables were researched from readily accessible publications to provide possible input into regression models. Pertinent categories of economic variables were chosen based on anticipated regression hypothesis. In most cases the categories were chosen to coincide with the "popular" statistics, i.e., those statistics that are frequently seen or heard in the public media and would influence a person's opinion about the state of the economy. Our hypotheses will be discussed in more detail in Chapter III, but we believed that any influence the economic indicators had on decisions to leave were based more on the perceived state of the economy than on those economic factors which would be statistically related to an individual (e.g.: the seasonally unadjusted, 20-25 year old, male unemployment rate would probably more accurately relate to a junior E-4's ability to find outside employment, but in reality an E-4 may base his expectations of civilian employment opportunities on the seasonally adjusted total unemployment rate that he saw reported in the news last week).

1. Consumer Price Index

CPI is the unadjusted CPI for all urban consumers, city average, for all items. The index of reference is 1967=100. Data was obtained from the Bureau of Labor and Statistics' CPI Detailed Report for FY81 - 86.

2. Unemployment Rates

Unemployment rates are the seasonally adjusted unemployment rates for men, 16 and over, 20-25 and 25 and over. Data was obtained from Table A-38 of BLS' Employment and Earnings Report (various volumes) for 1981- 1986. These categories were chosen as characteristic of the demographic makeup of the Coast Guard .

3. Gross National Product

GNP is in 1982 dollars. The annual rate was obtained for each quarter from 1981- 1986 from Table II-A-80 of Business Conditions Digest (various volumes). In order to convert this data to monthly figures, we assumed that the changes from month to month were linear and interpolated accordingly.

4. Pay Raises

The percentage of the annual pay raise for DOD (same as CG) obtained for 1981- 1986 from various issues of the Navy Times.

5. Data Modification

The described economic data was manipulated further, using differencing(one month, six month and twelve month), to make it more useful in the proposed linear regression model described in Chapter III.

The exogenous data used by the author is included in Appendix A. The differenced data is contained in Appendix B.

C. DATA ANALYSIS

Most of our data analysis was graphical. We were attempting to select variables and determine patterns that would assist in the development of various inputs to the Markov model we have proposed. A subsidiary benefit of this analysis is a concise, graphical representation of historic personnel policies. There are a number of trends and variations in the data that are not directly related to this analysis but might be of considerable interest to the CG policy maker (e.g. there is a trend toward a top heavy force pyramid). We used numerous analytic tools that are available on GRAFSTAT [Ref. 3] but found that the clearest results were obtained from time series plots , multiple box plots and scatter plots. Numerical summaries of the data were obtained through the SAS [Ref. 4] regression models used in Chapter III. We will discuss those aspects of the data analysis that had the most significance to our model development.

1. Stocks

A time series plot revealed an anticipated consistent drop in stocks during December and June. This observation will be developed further in the man year consumption portion of our model (Chapter IV). See Figure 2.1.

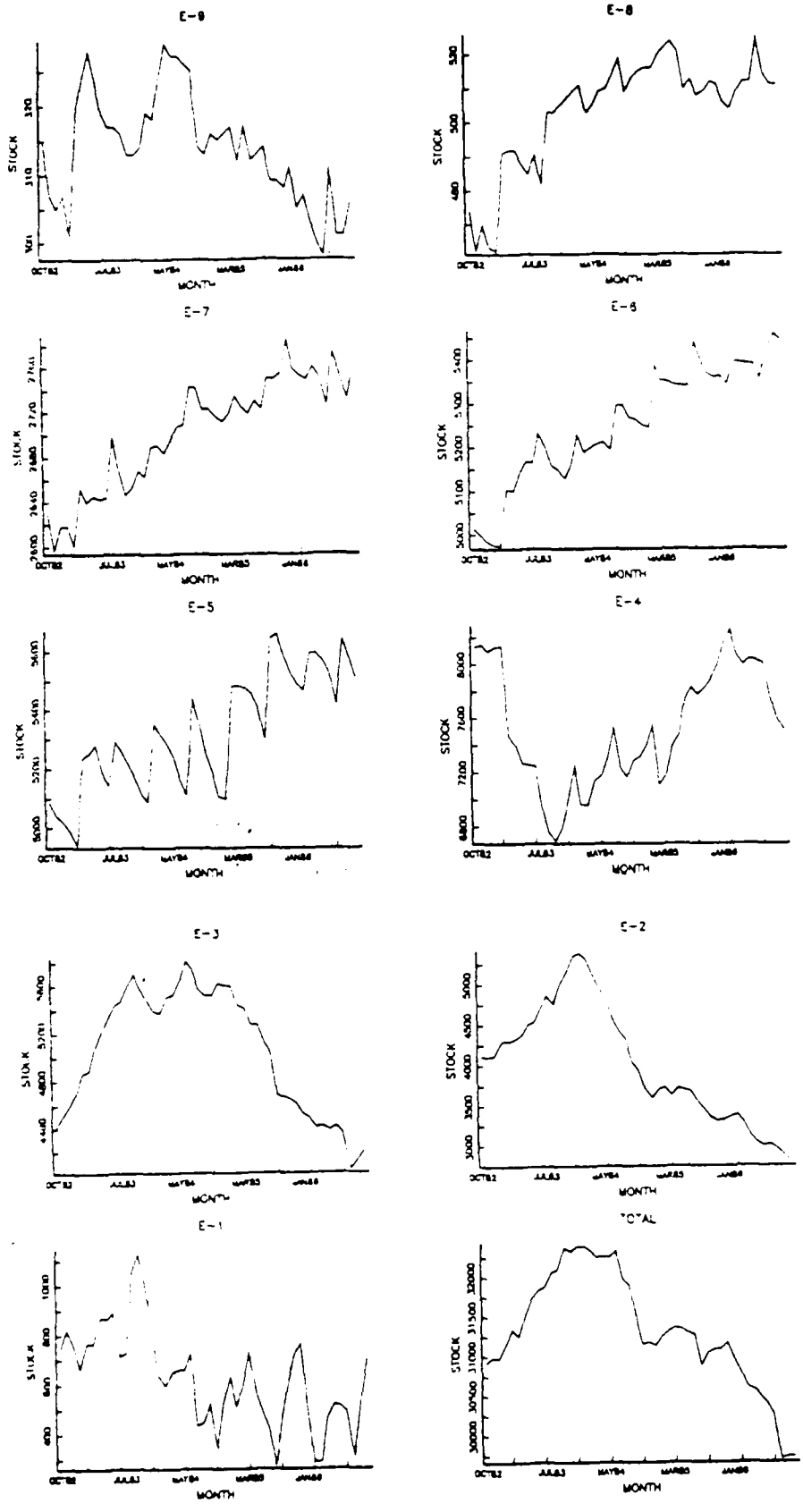

Figure 2.1 : Stocks

2. Attrition rates

A time series plot of the attrition rates revealed a possible time of year effect. See Figure 2.2. A multiple boxplot of the attrition rates, categorized by month and paygrade revealed a definite month effect, with a consistent spike in all cases in the summer months. See Figure 2.3. This effect will be exploited in the regression models.

3. Promotion rates

Multiple box plots categorized by paygrade and month revealed definite month effects with clear spikes in January and July. See Figure 2.4 and 2.5. This effect will be integrated in our regression model.

4. Recruits

A multiple boxplot of recruits as a percentage of the yearly total and as a percentage of quota obtained revealed a definite decline in recruiting levels in June and December and a consistent pattern of reaching the quota level in all months except December. See Figure 2.6. Figure 2.7 is a time series plot of recruits by month and paygrade. We attempted to discern any time of year effect other than the one mentioned above or any trends in the data. In general, we felt there were no significant effects. These observations will be used to develop model assumptions in the manyear consumption part of the model (Chapter IV) and will be integrated in the development of the recruitment proportion vector (Chapter III).

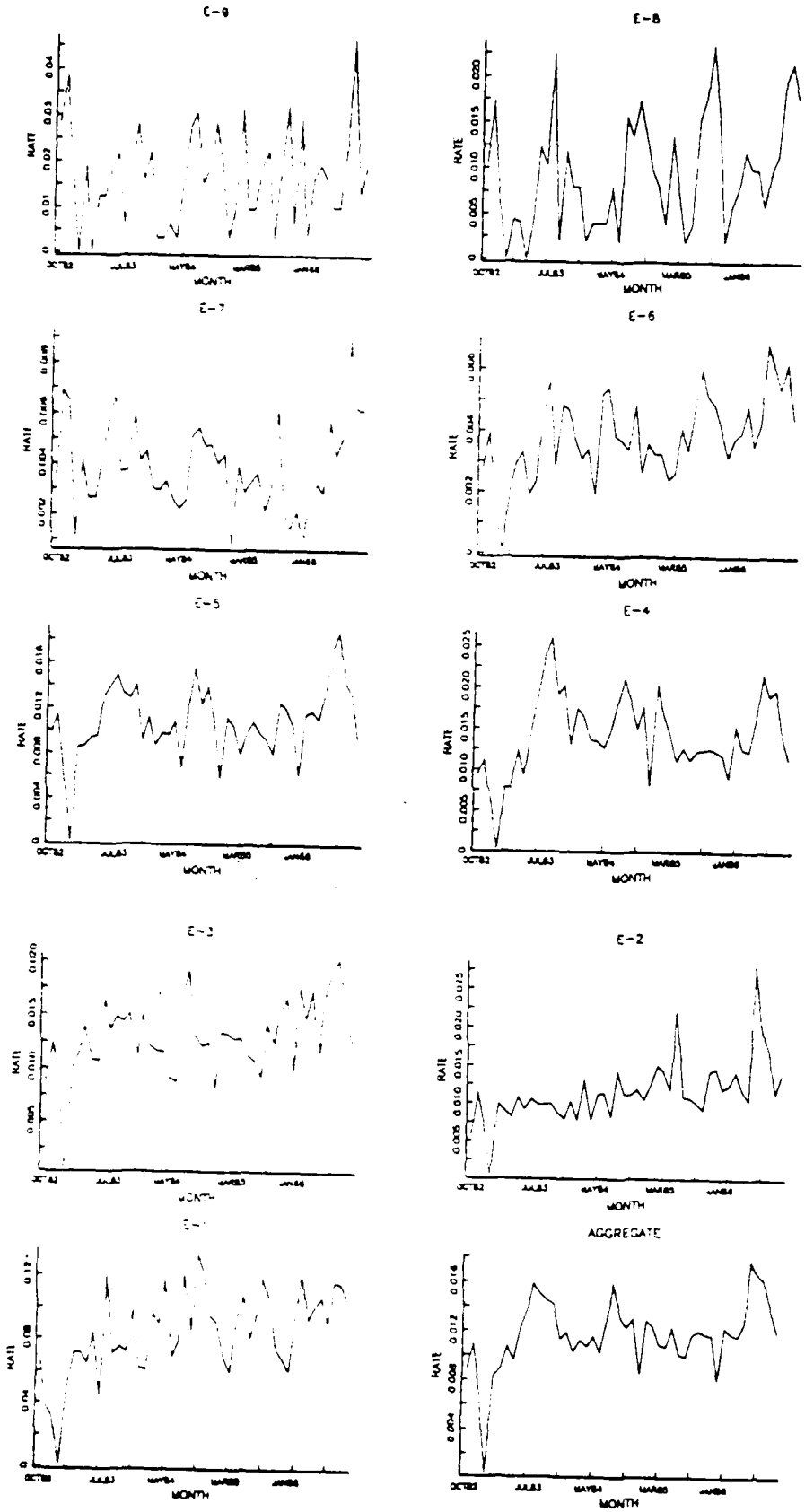

Figure 2.2 : Attrition Rates

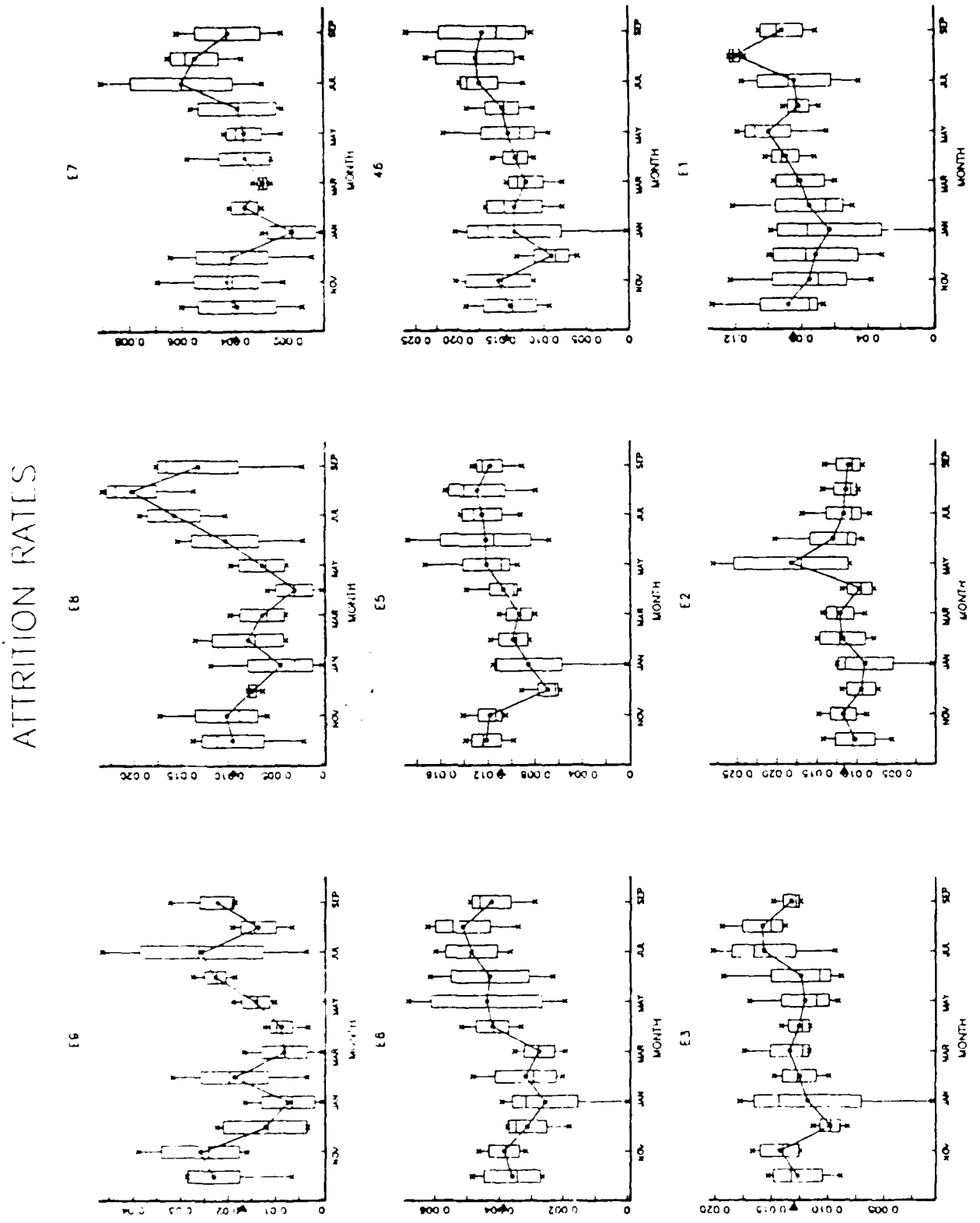

Figure 2.3 : Attrition Rates

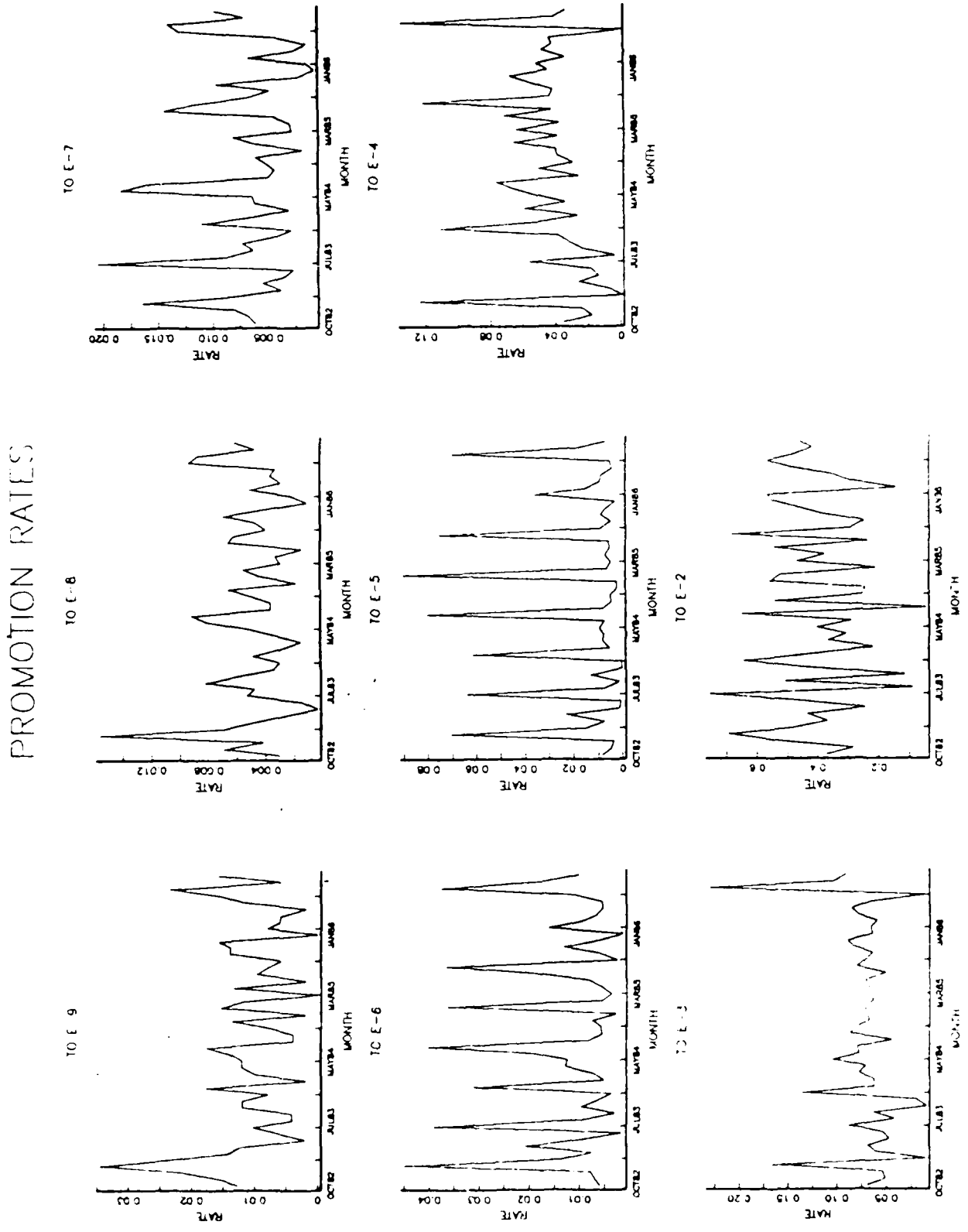

Figure 2.4 : Promotion Rates

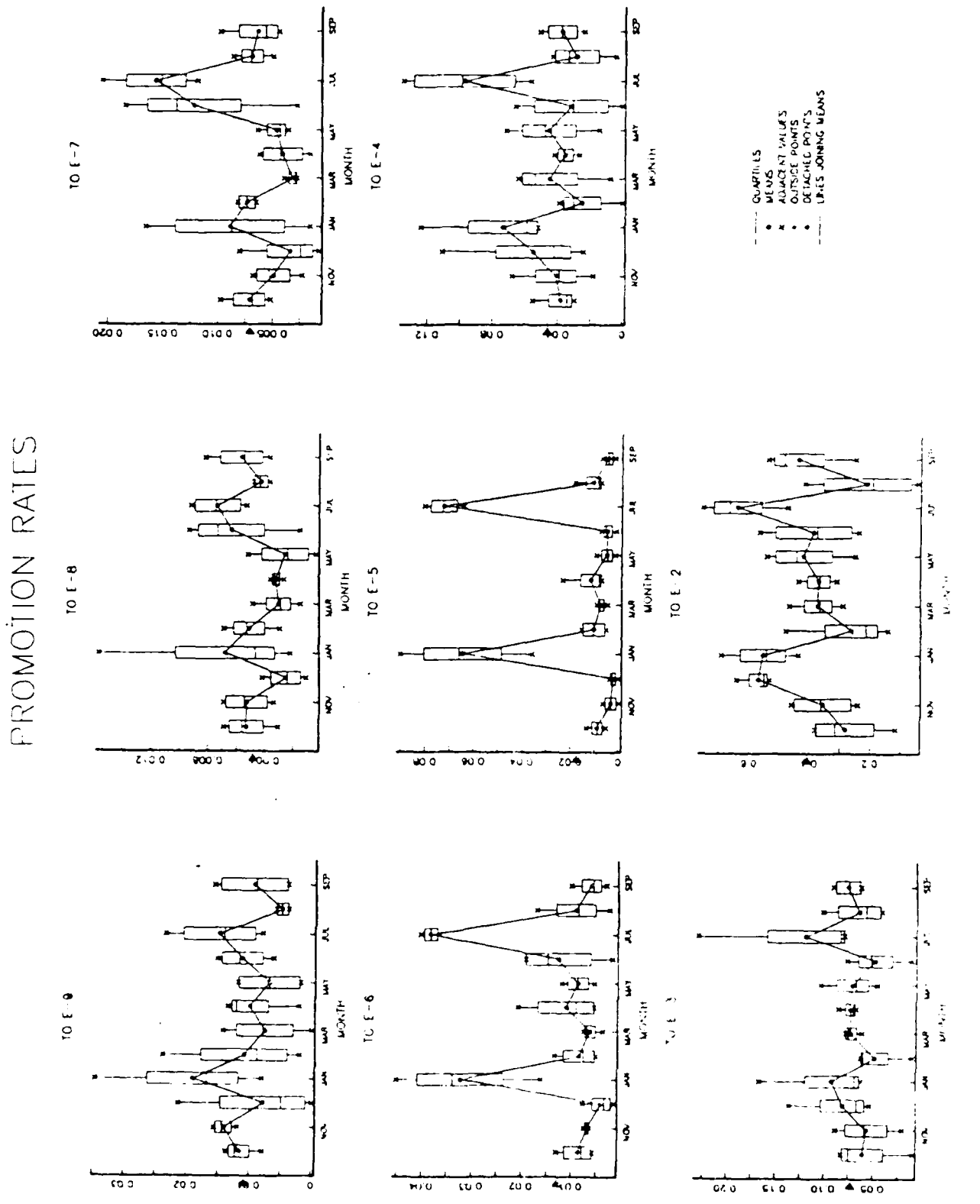

Figure 2.5 : Promotion Rates

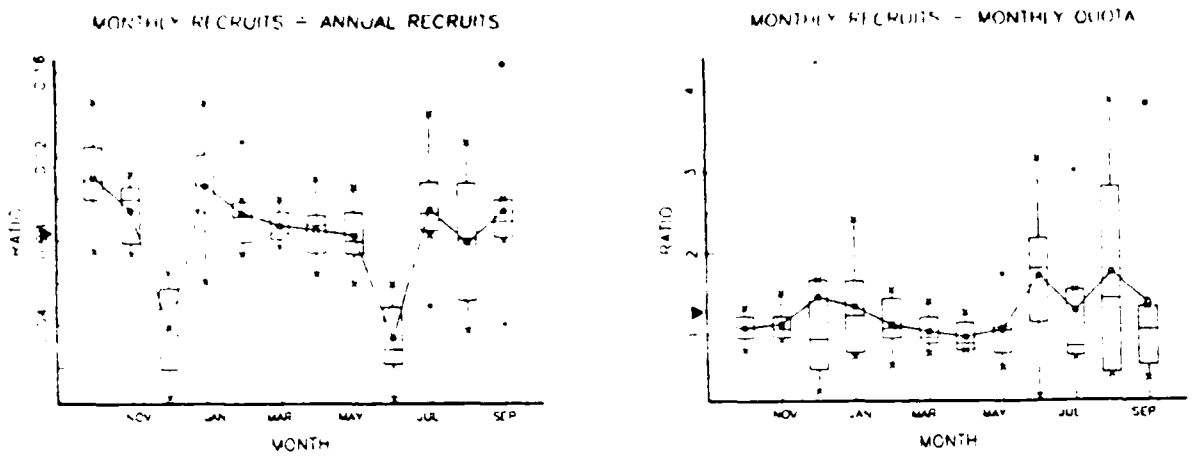

Figure 2.6 : Accessions

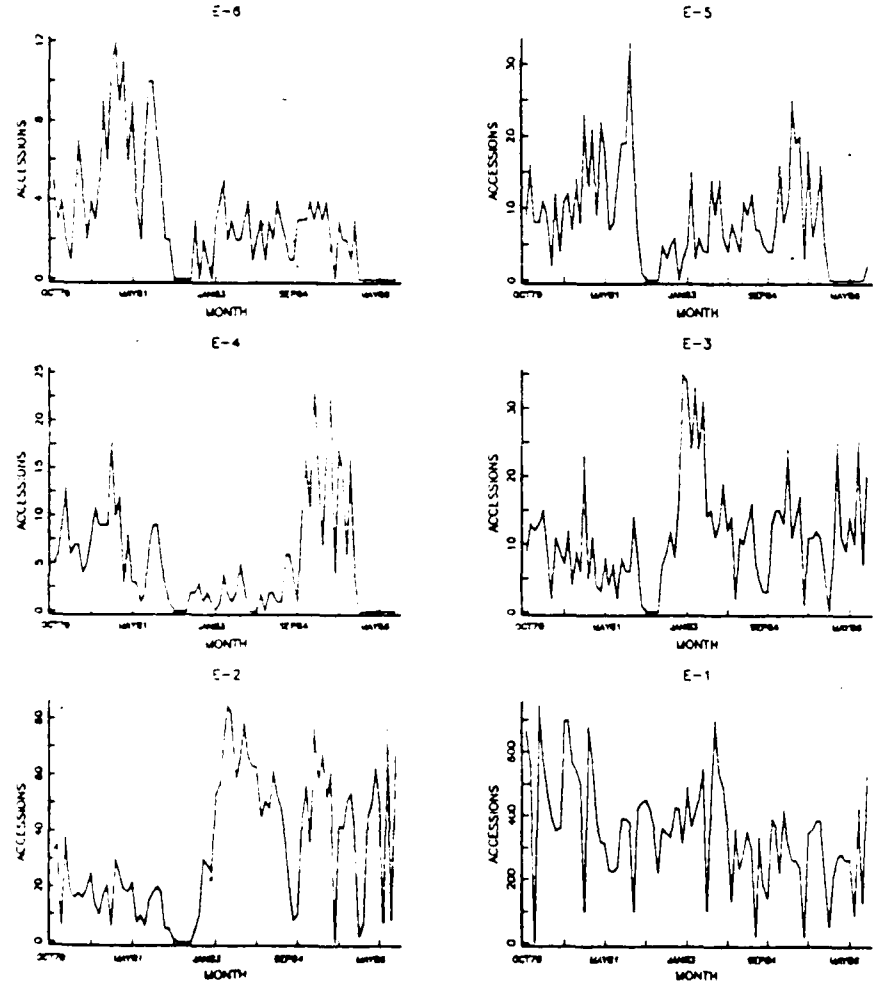

Figure 2.7 : Accessions

5. Billets

A time series plot of the billets was examined in conjunction with Figure 2.1 to examine probable correlations between stocks and billets (we expected that growth in the system would be reflected by a proportional change in the billets for each pavgrade). See Figure 2.8. We then examined a time series plot of billets divided by total force strength. This would indicate any changes in the actual billet pyramid. We observed that E-9 billets hovered at the maximum one percent. E-8 billets seemed to hover at about 1.6 percent with a possible increasing trend. E-6 and E-7 billets have experienced a definite upward trend, perhaps reflecting an increase in technical billets in the CG. E-5 billets appear relatively stable with a possible small increasing trend. E-4 billets seem to fluctuate widely. We suspect that this results from widely changing needs in lower level specialty levels as missions are added or redefined, as well as the relatively short time required to promote a raw recruit to this level of competence. The E-1 to E-3 billets appear to have sharp changes due to changing policies (large growth implies a large increase in E-1 billets) as well as some apparently arbitrary changes (see shift between E-2s and E-3s in May 1984). See Figure 2.9.

This led to an examination of a time series plot of actual stocks divided by the total stock to see if our historic personnel policies produced results correlated to

the planned structure. We observed a strong correlation between stocks and billets in paygrades E-4, E-6 to E-9. In paygrade E-5, it appears that the CG was significantly under authorized strength and has recently closed the gap. There appears to be little correlation in the paygrades E-1 to E-3. This is not surprising since the CG promotion policies in these categories are not tied to vacancies but are on an "as qualified" basis. See Figure 2.10. Lastly we examined a time series plot of stocks divided by billets which reflects how close our historic stocks relate to authorized strengths. We see that in the E-7 to E-9 paygrades, we are relatively close to 100 percent of billets. In paygrades E-5 to E-6, we are chronically under authorized strength. In paygrade E-4 we are chronically over authorized strength. These discrepancies are explained further in Chapter III. See Figure 2.11.

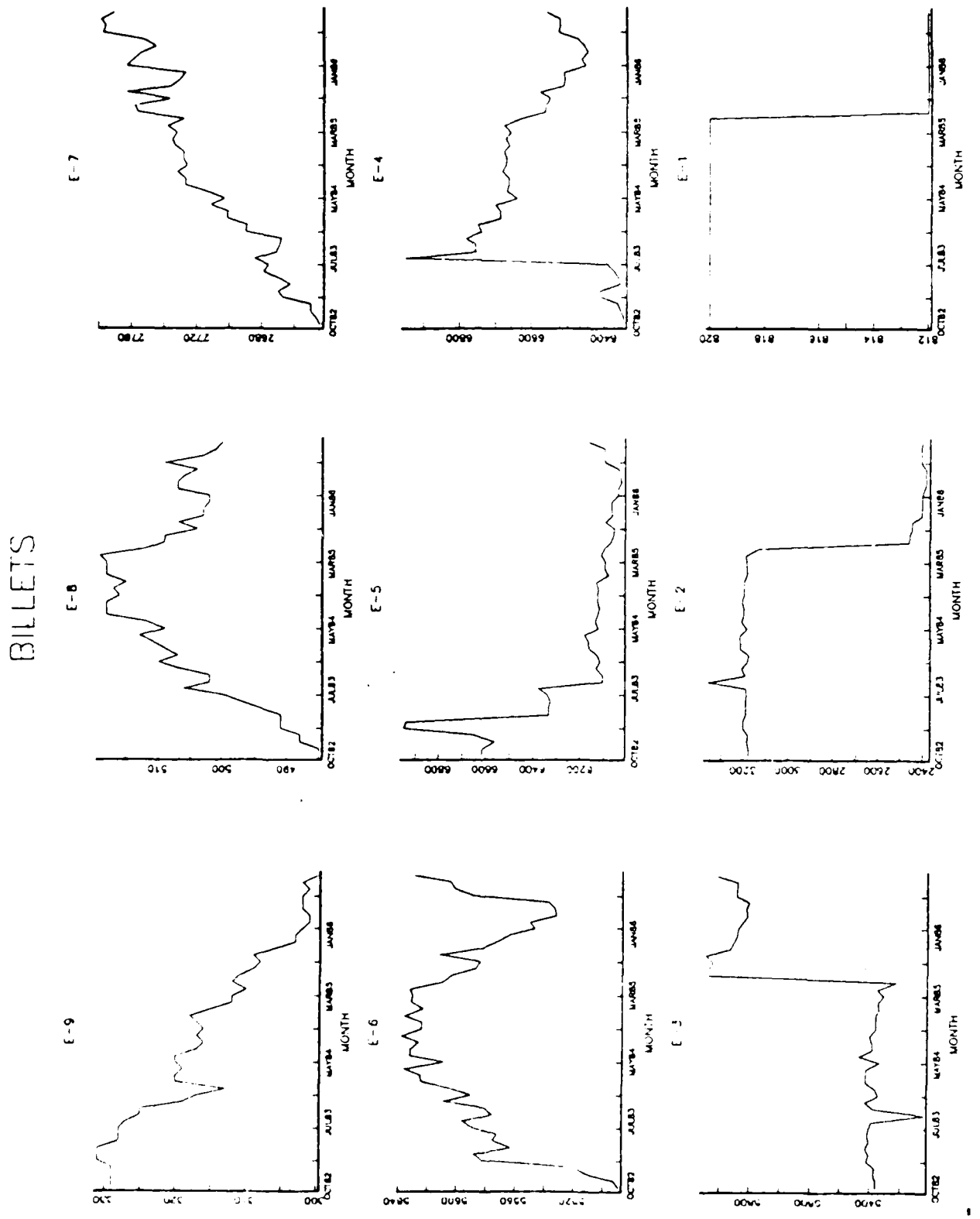

Figure 2.8 : Billets

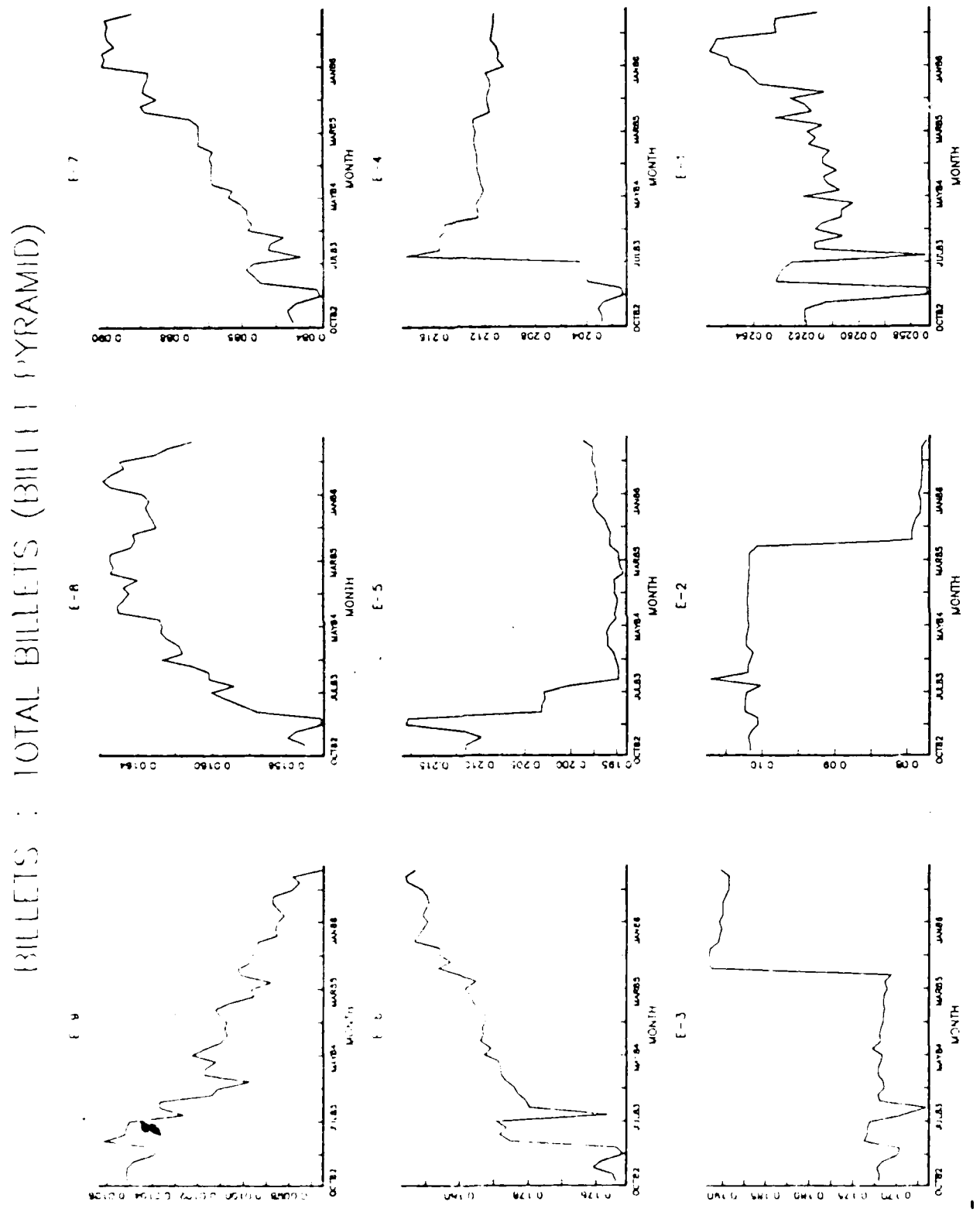

Figure 2.9 : Billet Pyramid

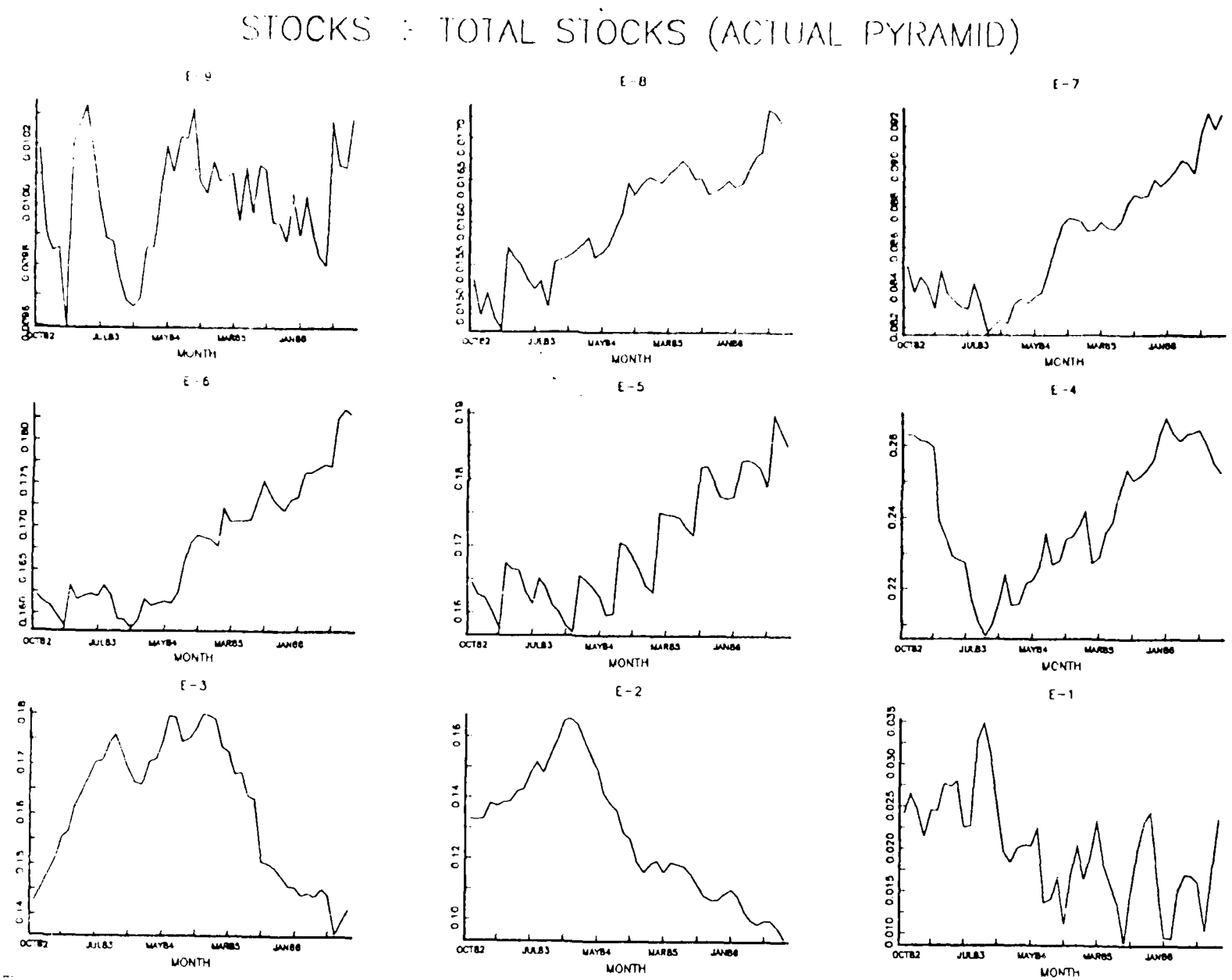

Figure 2.10 : Actual Pyramid

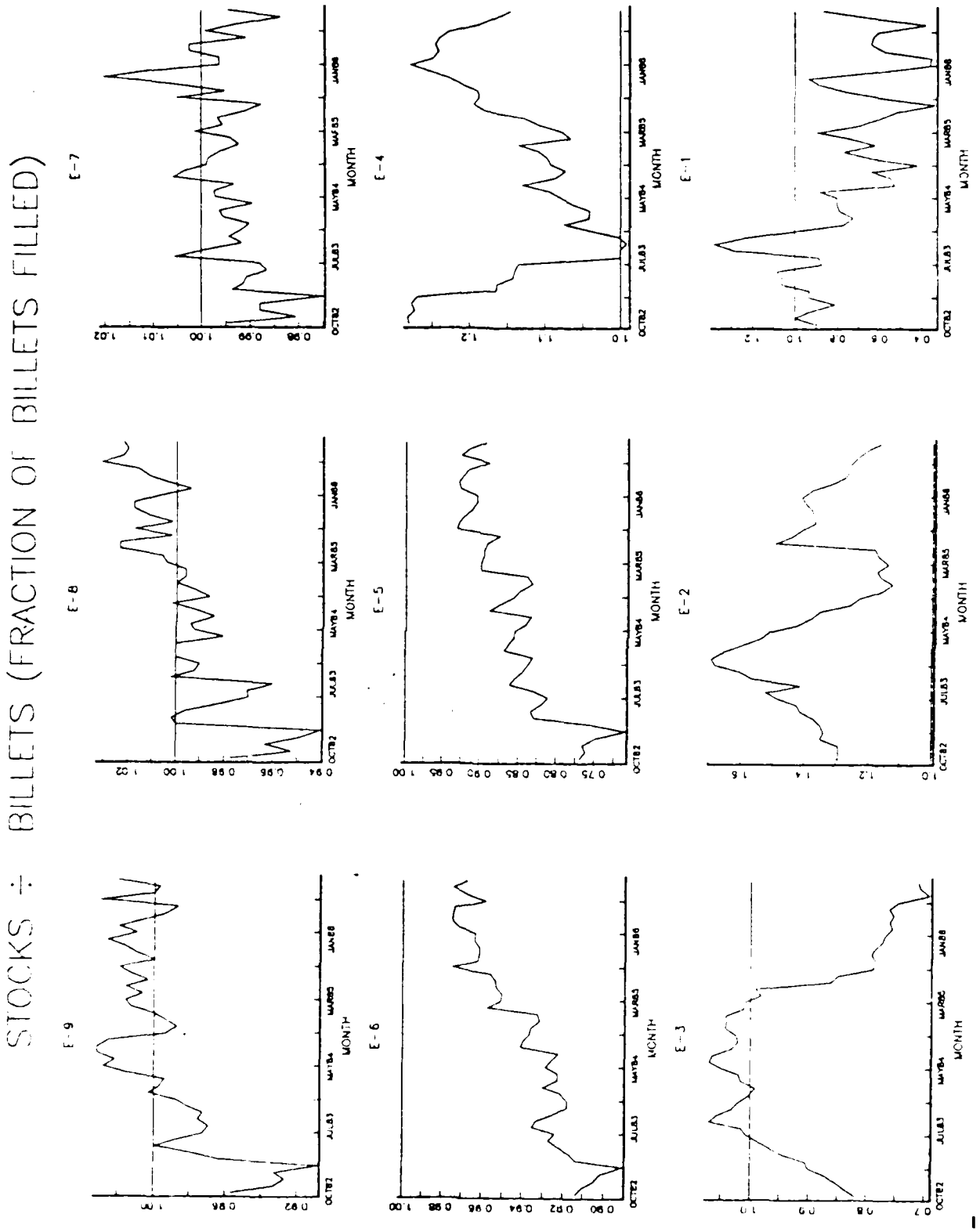

Figure 2.11 : Fraction of Billets Filled

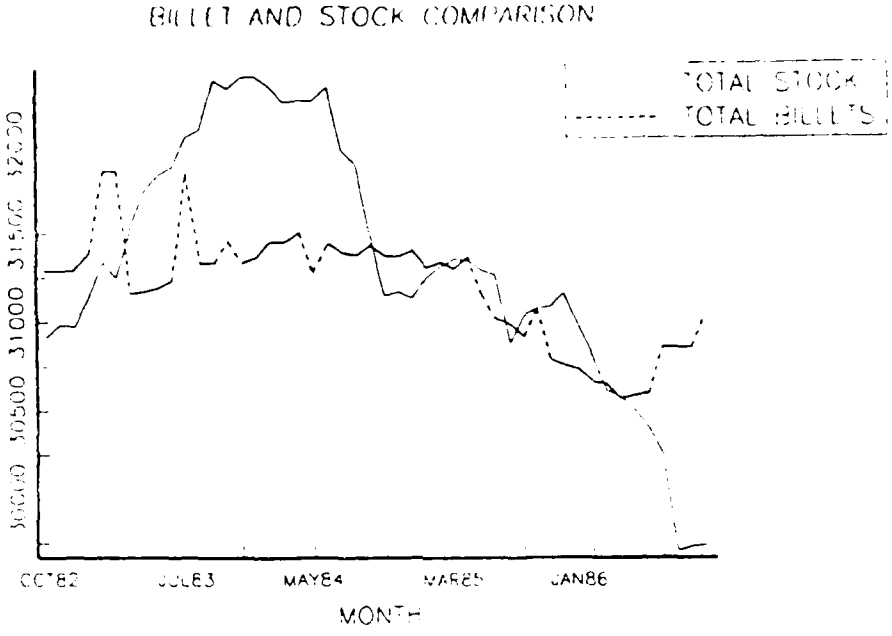

Figure 2.12 : Billet and Stock Comparison

III. MODEL FLOW RATE ESTIMATION

A. ATTRITION RATES ($W_{i,t}$)

Monthly attrition rates for each pay grade are needed for the Markov transition model presented in Chapter V. Aggregate attrition rates for June and December are used in the man year consumption portion of the model discussed in Chapter IV. The human behavioral nature of this flow rate makes it difficult to forecast accurately. It is difficult to make a general hypothesis about factors influencing decisions to leave an employer. We discuss below a reliable and consistent monthly forecast method developed for each paygrade. Areas where the forecasts may be improved will also be mentioned. In each of the three possible forecast methods discussed below, we developed ten cases for each forecast (nine pay grades plus the aggregate).

The notation developed in this section attempts to be consistent with the notation used by Batholemew and Forbes [Ref. 2:pp. 85-112]. It will be used throughout this paper.

Three different methods were considered in developing a model to predict the attrition rates. They were: an econometric linear regression model, a three year weighting scheme, and an exponential smoothing scheme. In order to compare the predictive quality of the three methods, we used the 1983 through 1985 data to forecast the attrition rates for 1986. We compared the sum of squares of the differences

between the forecast rate for 1986 and the observed 1986 data. In that sense, the best of these three models for predictive purposes proved to be the linear regression model.

The first model we examined was a three year weighted average of the data used to calculate flow rates suggested by Bres, et al [Ref. 5] in their personnel flow model. The model predicts the monthly attrition rate for each paygrade as follows:

1. Calculate a three year weighted average of the number of attritions, assigning weights of 1/6, 1/3 and 1/2 to the data, least recent to most recent respectively.
2. Calculate a three year weighted average of the stocks using the same weights.
3. The forecast attrition rate for the fourth year is calculated by dividing the weighted average attritions by the weighted average stocks.

The hypothesis is that the attrition rate during a particular month will be closely tied to the rate of the same month last year and progressively less closely tied to the rates of that month in the preceding two years.

The second model we examined was an exponential smoothing scheme described by Chatfield [Ref. 6:pp. 85-89] and which Hogan [Ref. 7] found useful in his estimations of Marine Corps personnel loss rates. Using this method, the equation for the estimated attrition rate can be written:

$$\hat{W}_i(t+1) = \alpha W_i(t) + (1-\alpha)\hat{W}_i(t)$$

where $W_i(t)$ is the observed attrition rate for paygrade i, time period t and

$\hat{W}_i(1) = W_i(0)$; α is selected to optimize the model.

This model was applied for each paygrade and month combination. This limited each model to four data points. We attempted to remove the time of year effect so that we could apply this model across all 48 data points but we were not successful in removing the month effect. As more data becomes available, this analysis would appear to have more merit, possibly extending the flexibility of the attrition rate forecasts.

The third model we considered was an econometric regression model:

$$\hat{W}_i(t) = \hat{\beta}_0 + \sum_j \hat{\beta}_j X_j(t) + \epsilon ,$$

where $W_i(t)$ = attrition rate for paygrade i during month t

β_j = coefficient estimate for the carrier variable j

$X_j(t)$ = observed value of the jth carrier variable in month t.

ϵ = error component with assumed distribution $N(0,\sigma^2)$.

The hypothesis was that the tendency to attrite would be influenced by a combination of internal factors and external economic factors which could either be anticipated exactly (e.g. expiration of enlistments) or forecast with relative accuracy (e.g. unemployment rates). In considering possible carrier variables it was important to remember that this was only a small part of the total model and inputs would have to be limited to make the model practical. The end user of the

model needs a model with inputs that are easy to obtain . A complicated model would discourage use because of the data collection necessary to make it work. We also took into consideration the selection of variables for which data are readily available from other offices at CG Headquarters. We also examined the abundant number of similar models that have been developed in this area for other military services. The variables we considered using were broken into two categories (abbreviations are SAS variable names).

1. Dependent Variables

The attrition rate for each month for each paygrade and the aggregate attrition rate for the month. (E1,E2,..., E9,EALL)

2. Independent Variables

We initially considered the concurrent levels of the economic indicators as dependent variables. The resulting poor regression fit led us to attempt to difference all economic indicators because we hypothesized that individuals reacted to changes (is it getting better or worse?) in the economy when making decisions.

a. Consumer Price Index for all Goods CPI

This variable is considered for inclusion after differencing one, six, and twelve months. (CPI1,CPI6, CPI12)

b. Gross National Product (GNP)

This variable is considered for inclusion after differencing one, six and twelve months. (GNP1, GNP6, GNP12)

c. Unemployment rate

We initially considered the urban, seasonally adjusted rate for white males, based on the demographic make up of the CG. The variable was also considered in the additional age categories : 16+, 20-25, 25+. This variable was differenced six months in all cases. (E20LAG, E25LAG, ETOTLAG). We eventually settled on the aggregate unemployment rate differenced six months because it is the most readily available rate for which forecasts are available for the next twelve months. We were satisfied with this substitution because examination of the differenced values indicated that all the indicators tend to move in the same direction with the same relative increments.

d. Pay difference (PDIF)

This variable attempts to capture the change in purchasing power of the enlisted person. It is the difference between the CPI differenced twelve months and the last pay raise . This variable was suggested by CPT Higham [Ref. 8] in an Army SRB model and was used with good success.

e. Expiration of enlistments (EENR,EESUB,EE1ST)

This is the projected number of enlistments that will expire in a month for the aggregate paygrades E-1 through E-3, first term and subsequent enlistments.

f. Recruits

This is the number of E-1 recruits entering the system in the last month and 2 months ago.(INLAG1,2)

3. Forced Variables

These are independent variables included in all possible models. We included a variable to account for the time of year effect discussed in the data analysis section. We examined two different schemes to account for this effect:

a. Dummy variables were assigned to each data point. This method entails using 11 binary variables to account for 12 months. For example, the variable:

$$X1 = \begin{cases} 1 & \text{for January} \\ 0 & \text{for all other months} \end{cases}$$

Similar assignments are made for the other variables X2, X3,..., X11.

b. The data suggested the time of year effect may be captured with a higher order model (second, third or fourth order seemed most likely after examining the data). A month variable was generated that was coded October = 2, December = 3, ... , September = 1. This coding was indicated by examining the data. It appeared that the polynomial time of year effect started in September rather than in October. Additional variables were generated from the month variable (MNTH) by raising the month variable to the second, third and fourth power (M2, M3, M4).

4. Other Variables

After using the above variables, we also considered the usefulness of the following variables.

a. Selective Reenlistment Bonus.

This data is not categorized by month or paygrade and a transformation of the data would be necessary. We suspect that this variable would be what Tukey [Ref. 9:pp. 316-317] calls a proxy for economic variables mentioned earlier.

b. Average age, Time in Service, Time in grade.

This data was incomplete and not categorized by month.

5. Selecting the Variables

The method of selecting the variables to use was facilitated with two procedures available in SAS: Stepwise regression and the R-Square procedure.

The first step after determining appropriate candidate variables was to use the stepwise regression procedure to begin the variable selection process. The results are summarized in Table 3.1. The stepwise selection procedure selected one of the CPI variables in eight out of the ten cases. It selected one of the GNP variables in four out of the ten cases. It only selected an unemployment rate variable in one case. It selected the pay difference variable in five out of the ten cases. It selected an expiration of enlistment variable in six out of the ten cases. It selected the recruit variable in four out of the

ten cases. There did not seem to be a consistent selection of one particular differencing (one, six and twelve months) for any of the variables . We eliminated the dummy variable representation of the months from consideration because we discovered that we could get comparable results from a fourth order model, consuming four degrees of freedom. The dummy variable representation consumed eleven degrees of freedom to obtain the same quality of fit. In a regression model, it is desirable to minimize the number of parameters being estimated.

TABLE 3.1 STEPWISE REGRESSION RESULTS

Independent Variable	E-9	E-8	E-7	E-6	E-5	E-4	E-3	E-2	E-1	EALL
Month	X	X	X	X	X	X	X	X	X	X
Month^2	X	X	X	X	X	X	X	X	X	X
Month^3	X	X	X	X	X	X	X	X	X	X
Month^4	X	X	X	X	X	X	X	X	X	X
CPI diff1		X	X		X	X	X	X		X
CPI diff12						X		X	X	X
GNP diff1							X		X	
GNP diff6			X							
GNP diff12						X				X
Unemply 20-25			X							
Pay diff		X	X		X		X	X		
Exp Enl NP				X			X			
1st						X			X	
sub				X			X			
total					X	X			X	X
Recruit lag1		X								
lag2					X			X	X	X
R-Sq	.27	.69	.43	.54	.60	.77	.57	.56	.65	.67
Cp	1.6	13.4	5.0	7.8	7.8	6.2	.72	5.5	1.6	4.5

The next step in the variable selection process was to deal with two problems. First, there were variables that the stepwise regression selected that did not have intuitive appeal (e.g. the model for E-8 attrition rate selected the number of E-1 recruits entering the service in the preceding month). Secondly, we desired to have a consistent model for each paygrade that used more or less the same variables. We utilized the RSQUARE procedure to facilitate the refinement of the variable selection. The RSQUARE procedure allowed us to see if there were other variable combinations different from the ones selected by the stepwise regression procedure that provided a comparable quality of fit. The results of this analysis and selection process are summarized in Table 3.2 . The RSQUARE procedure helped considerably in this selection. Some of our decisions to select variables , however, were based on the desire to have a consistent model. For example, the RSQUARE procedure indicated that the unemployment variable was statistically insignificant for paygrades E-1, E-2 and E-9, however, it was statistically significant for the other paygrades. We decided to include the unemployment variable in all cases (each paygrade) of our models to make them consistent with each other. Note that the R-squared values obtained with the selected variables in Table 3.2 are about the same as those obtained with the stepwise regression in Table 3.1.

TABLE 3.2 REGRESSION VARIABLE SELECTION

Independent Variable	E-9	E-8	E-7	E-6	E-5	E-4	E-3	E-2	E-1	EALL
Month	X	X	X	X	X	X	X	X	X	X
Month^2	X	X	X	X	X	X	X	X	X	X
Month^3	X	X	X	X	X	X	X	X	X	X
Month^4	X	X	X	X	X	X	X	X	X	X
Pay difference	X	X	X	X	X	X	X	X	X	X
CPI differenced one month	X	X	X	X	X	X	X	X	X	X
GNP differenced six months	X	X	X	X	X	X	X	X	X	X
Expiration of enlistments, subsequent	X	X	X	X	X					
Expiration of enlistments, first					X	X				
Expiration of enlistments, non-rate							X	X	X	
Expiration of enlistments (total)										X
Unemployment rate total, 16+ diff six months	X	X	X	X	X	X	X	X	X	X
recruit lag1									X	
recruit lag2 months ago									X	
R-Sq	.38	.65	.42	.51	.60	.68	.58	.48	.61	.66

Lastly, each of the ten linear regression models resulting from the variable selection process described above were evaluated with diagnostics available in the SAS procedure REGRESSION. See Appendix B. We observed no significant collinearity among the variables . Using Cook's D statistic, and the diagonal of the Hat matrix [Ref. 10:pp 170-175], we observed outliers (observations of JAN 83 and MAY 86) with possible significant impact on the regression. We examined the model without these observations and did not obtain any significant improvement. We examined the results for possible violations of the assumptions required for linear regressions (normality of the residuals, homoscedasticity, linearity of the model, independence of the carrier variables) and found no evidence that these assumptions are untenable. The REGRESSION procedure also provided the estimated parameters for each model which are summarized in Table 3.3 .

The results of the three candidate models were evaluated, as discussed previously, by comparing the sum of the squares of the differences between the forecast value for 1986 and the observed data. There is an obvious bias toward the regression model in this comparison because it utilized 1986 data in developing the parameters. The alternative would have been to use 1983 through 1985 data to estimate the parameters and then to forecast the 1986 values. There were nine to eleven degrees of freedom utilized by the model and we felt a

TABLE 3.3 ATTRITION RATE MODEL COEFFICIENTS

Variable	E-9	E-8	E-7	E-6
INTERCEP	0.01067604	0.01577605	0.004863766	0.001431995
MNTH	0.01525133	-0.003886160	0.000245262	0.000688187
M2	-0.006107779	0.000729881	-0.000162754	-0.000327988
M3	0.000771957	-0.000087567	0.000019622	0.000043157
M4	-0.000030584	.00000473142	-5.91827E-07	-0.000001634
PDIF	-0.10579793	-0.07331790	-0.07361733	-0.004572339
CPI1	1.17547549	0.53356223	0.17835560	0.07897454
GNP6	-0.10934948	-0.16153493	-0.01817683	-0.002734301
EESUB	.00000443804	.00000718083	-.0000039631	.00000816324
EMPLAG	0.01936890	-0.008052806	0.001973756	-0.004426700

	E-5	E-4		Total
INTERCEP	0.005382164	0.005869708	INTERCEP	0.006831735
MNTH	0.000585879	-0.001017229	MNTH	-0.000349264
M2	-0.000449154	0.000057722	M2	-0.000060927
M3	0.000065590	1.03404E-07	M3	0.000012682
M4	-.0000026832	1.94522E-07	M4	-4.16848E-07
PDIF	-0.10081540	-0.12075055	PDIF	-0.07808159
CPI1	0.49057364	0.55959220	CPI1	0.44951882
GNP6	0.01639801	0.03545172	GNP6	0.005240226
EESUB	.00000340662		EETOT	.00000747545
EE1ST	0.000013034	0.000028291	EMPLAG	-0.007287778
EMPLAG	0.000851757	-0.01327953		

	E-3	E-2	E-1
INTERCEP	0.003427755	0.004910380	0.160976[illegible]
MNTH	0.002763041	0.004754049	-0.01764010
M2	-0.000662970	-0.001799222	0.001128531
M3	0.000055978	0.000251901	0.000165846
M4	-.0000014417	-0.000011088	-0.000013300
PDIF	-0.13333437	-0.11082705	-0.68051387
CPI1	0.67941224	0.63767360	0.63015861
GNP6	-0.07198693	-0.29187216	-0.44850907
EENR	0.000067688	0.000060013	-0.00009261[illegible]
EMPLAG	-0.01096783	-0.03206519	-0.17464429
INLAG1			-.0000047658
INLAG2			-0.000116962

Note: Variable names correspond to the SAS program found in Appendix B.

25 percent reduction of data points used to estimate the parameters would significantly decrease the fit of our model. The regression model was also favored because it includes a number of external factors affecting attrition that the decision maker would expect to be important. The other two models consider the attritions to be essentially a time series.

The results of this comparison confirmed the regression model as the best of the three in this case and are summarized in TABLE 3.4.

TABLE 3.4 RESIDUAL COMPARISON

Method	Σ(predicted-actual)^2
Regression	.006623
Weighted	.0240
Exponential	.05772 (α= .82)

The linear regression model was the only model of the three for which the residuals appeared to be normally distributed.

The regression model should be used with the following comments in mind:

1. Tukey [Ref. Pidd. 331] has discussed some dangers in using a regression for predictions. The range of economic indicators for 1983 - 1986 was small (relative economic stability). Caution should be used when extrapolating beyond the range of the carriers used to develop this model. It is recommended that the model

be reassessed when the observed data exceeds the ranges of the data listed in Table 3.5, used to develop this model. The model should be regularly reassessed and updated as more data becomes available.

TABLE 3.5 RANGE OF CARRIER VARIABLES

Variable	Maximum	Minimum
Pay Difference	.0157	-.0187
CPI differenced 1 month	.0075	-.01149
GNP differenced 3 months	.0506	-.0031
Unemployment differenced 6 months	.1368	-.180
Expiration of Enlistment	535	19

2. Additional uncertainty is introduced to the model because we will normally use quarterly forecasts of economic indicators and will interpolate monthly values.
3. Policy changes can have a significant effect on the model. Even as this model was developed, a significant reduction in E-1 attritions took place due to major changes in the discharge procedures at the CG recruit training center. Since we felt that these changes were long term, and we were able to observe from the first six months of the 1987 data that the attrition rate had dropped by 35 percent, we modified the E-1 and the aggregate attrition rates as discussed in Chapter II.

Additional policy changes such as a two year enlistment and a two year extension policy are being considered or have been implemented since this model was developed. The impact of these and other changes is unknown and should be considered when using the model. The output of the regression model will be integrated into the spreadsheet application of the entire model and the user can test the effect of these policy changes by overriding the default attrition rates generated by the regression anaylsis.

B. RECRUITMENT VECTOR

Accessions may occur into any paygrade as described in Chapter II. Our recruitment vector, r(t), will be a vector of nine elements which are the accessions to paygrades E-1 to E-9 respectively for month t. The data examined indicates that the last three elements (E-7 to E-9) of the r(t) vector should be zero. An examination of the data as described in Chapter II lead us to the hypothesis that for paygrades E-3 through E-6, the monthly number of accessions are constant over time. Our hypothesis for E-2 accessions is that the monthly accessions are the same for all months except December and June. E-1 accessions are the result of policy decisions (recruit quotas) which this model hopes to influence. We were not able to observe any time correlation among the E-2 through E-6 recruits in the four years of data. We conducted a one-way analysis of variance to test

the hypothesis just described. In all cases we found that at a significance level of $\alpha = .05$, we could not reject our hypothesis that the monthly accessions were constant over time. The results are summarized in Table 3.6.

TABLE 3.6 ANOVA FOR ACCESSIONS

3.6.a ANOVA Table Accessions E-6

Source	SS	df	MS	F-ratio
Month	52.4000	11	4.764	.537
Error	549.762	62	8.867	
Total	602.162	73		

$\bar{r}_6 = 3.5678 \approx 4$

3.6.b ANOVA Table Accessions E-5

Source	SS	df	MS	F-ratio
Month	299.4093	11	27.219	.561
Error	3010.4286	62	48.555	
Total	3309.8378	73		

$\bar{r}_5 = 9.595 \approx 10$

3.6.c ANOVA Table Accessions E-4

Source	SS	df	MS	F-ratio
Month	164.177	11	14.925	.404
Error	2290.810	62	36.949	
Total	2454.989	73		

$\bar{r}_4 = 6.014 \approx 6$

TABLE 3.6 (Continued)

3.6.d ANCVA Table Accessions E-3

Source	SS	df	MS	F-ratio
Month	797.936	11	72.521	1.223
Error	3675.143	62	59.276	
Total	4472.378	73		

$\bar{r}_3 = 11.041 \approx 11$

3.6.e ANCVA Table Accessions E-2

Source	SS	df	MS	F-ratio
Month except DEC, JUN	1936.692	9	215.188	.329
Error	33983	52	653.537	
Total	35920.597	61		

$\bar{r}_2$(except DEC,JUN) = 32.73 $\approx$ 33

$\bar{r}_2$(DEC) = 22.0 $\approx$ 22

$\bar{r}_2$(JUN) = 12.4 $\approx$ 12

Based on the analysis and the discussion above the following estimations were used for the recruitment vector.

The estimated accessions for E-3 to E-6 is the average of accessions over 74 months (OCT 79 to NOV 85).

The estimated accessions for E-2 is the average of accessions over 74 months. The estimate for December is the average of six Decembers (1979 - 1985). The estimate for

June is the average of June accessions during 1979-82 and 1984-85 (1983 was rejected as an outlier).

E-1 accessions are estimated by subtracting the accessions estimated above for paygrades E-2 through E-9 from the total monthly accessions (R(t)). Total monthly accessions are calculated by subtracting last month's attritions (i.e. attrition rate times the stock) from the forecast total stock for this month (N(t)). Computation of N(t) is described in detail in Chapter IV.

The total accession equation is:

$$R(t) = N(t) - \sum_{i=1}^{9} [1-W_i(t-1)]*n_i(t-1)$$

Then E-1 accessions are:

$$r_1(t) = R(t) - \sum_{i=1}^{9} r_i(t)$$

The average accessions, $\bar{r}_i$, for paygrades E-2 through E-9 are summarized above in Table 3.6.

Periodically the CG decides to restrict accessions in paygrades E-- to E-3. In this case the model may use the same estimates for paygrades E-1 to E-3 and zero for E-4 to E-6. We examined whether this change in policy had any effect on E-2 and E-3 accessions but could not determine any significant changes as the result of this policy variation. Our data under this type of policy change was limited to ten months (December 1985--September 86) and we recommend

further evaluation of the assumption that there is no effect on E-2 and E-3 accessions as more data becomes available.

C. PROMOTION RATE

A brief description of the promotion process, expanding on our comments in Chapter I is useful to clarify the derivation of the flow rate estimations developed here.

Vacancies in this model are defined as the difference between the authorized strength (number of billets) for a paygrade and stocks in that paygrade. Billets can be generally divided into two categories--field units (operational and support) and general detail (personnel in transit,leave enroute to next duty station, imprisoned, extended hospitalization,undergoing extended training or schooling, and personnel in non-specialty jobs such as recruiting). Billets are essentially limited to one and two percent of the total force strength for paygrades E-9 and E-8 respectively. The basic billet pyramid (distribution) is based on historical precedent which in some cases is based on well documented needs (a ship or airstation's standard organization) and in other cases based on undocumented heuristic decision processes developed as changes and needs were managed. Billets are generally added and subtracted from each paygrade as units are authorized (new ships or airstations) or decommissioned, or as new missions are added by Congress. Changes in units and types of units usually have prescribed manning levels, however, if these violate

other mandated size constraints, then ad hoc changes are made. New missions frequently have no clear cut personnel structure and the changes created are difficult to estimate. There are efforts in progress to quantify these requirements, most notably in the general detail portion. Other studies are being conducted to evaluate the legitimacy of the current structure. The best generalization that seems to be possible from examining the current method of modifying the billet allowances is that in the short term (one year), the ratio of the number of billets in a paygrade to the total monthly force strength remains the same over time (from one month to the next).

Promotions attempt to fill billets as fully as possible from the top down. If a vacant billet cannot be filled from the grade below, the CG attempts to fill it with the next lower paygrade. This procedure terminates at the E-5 level. The process is further complicated because the actual promotion process is categorized by rating (specialty) as well as paygrade. Some ratings have histories of chronic shortages due to favorable civilian employment opportunities. Our model is not concerned with the ratings but we will consider the effect of rating shortages when calculating the number of billets that will remain unfilled. Careful examination of the process seems to indicate that we can view the process without regard to ratings and still not reduce the quality of our estimations.

Promotions can be broken into two general processes.

1. Promotions to paygrades E-5 through E-9

Promotions are calculated from paygrade E-9 downward as follows:

a. The stocks from the first day of the current month are obtained from PMIS database.

b. The following personnel movements are subtracted from stocks:

(1) Non-reenlistments

An estimated attrition rate is applied to known enlistment expirations for the current month. In the smaller paygrades (E-8, E-9) these attritions may actually be anticipated by the assignment officers who are assumed to have more current and accurate information than the database.

(2) Retirements

Retirements for the upcoming month are anticipated by letters on file.

(3) Anticipated warrant officer promotions

(4) Promotions to the next higher paygrade.

c. The result of subtracting the above personnel movements from the beginning of month stocks is the anticipated end of month stocks prior to promotions to the paygrade.

d. This projected stock is subtracted from the planned billet strength for the paygrade to determine the

number of vacancies for the next month. These vacancies are then filled with promotees from the next lower paygrade. Vacancies which cannot be filled due to insufficient personnel eligible for promotion are carried down to the next paygrade.

There are procedures to account for changes in the general detail which may cause overages (i.e. the number of billets is decreased even though no attritions occur). For examole, an E-8 may be filling an E-8 recruiting billet (this is a general detail billet and not a specialty billet). If there is a vacancy for an E-9 in his/her specialty and he/she is the senior person eligible for promotion, he/she will be promoted. However, the specialty vacancy remains unfilled because the promoted E-8 is not eligible for transfer to fill that billet . Additionally his/her status as an E-9 in a general detail billet is exempt from statutory upper limits for that paygrade (i.e. that E-9 doesn't count toward the one percent constraint). CG policy is to promote the next eligible E-8 personnel to fill that E-9 specialty vacancy. Later, it is possible for the E-9 in the recruiting billet to be transferred back into his/her specialty. Both persons are now counted against the specialty billets, and if there were no attritions from that paygrade, the CG is now overfilling the E-9 billets. The purpose of this illustration is to demonstrate the minor policy variations that could account for overfilling of vacancies, especially

in the upper paygrades. The numbers involved are so small that we will consider them insignificant for this model.

2. Promotions to paygrades E-2 through E-4

These promotions occur on an as qualified basis. When an individual has completed the requirements for training, time in service and paygrade, and demonstrations of competence, he/she is promoted. Personnel in paygrades E-2 and E-3 essentially fill the same jobs, therefore the DG does not regulate the promotions to E-3 other than to determine the requirements described above. The promotions to paygrade E-4 are mainly regulated through the use of A-school (specialty training required for many ratings) quotas and the service wide examination for the small portion of individuals who "strike" (qualify through equivalent on-the-job training) for their specialty. All qualified "strikers" are advanced on 1 January and 1 July. These two methods attempt to keep the E-4 stocks in line with the authorized billets and unfilled vacancies which have been carried down from the upper paygrades. Figure 3.1 is a graph of the number of the cumulative, unfilled vacancies in the E-4 and above paygrades during the period October 1982 through September 1986. Positive numbers indicate vacancies and negative numbers indicate that cumulative stocks exceed billets. It appears that the process of carrying the vacancies down varied considerably.

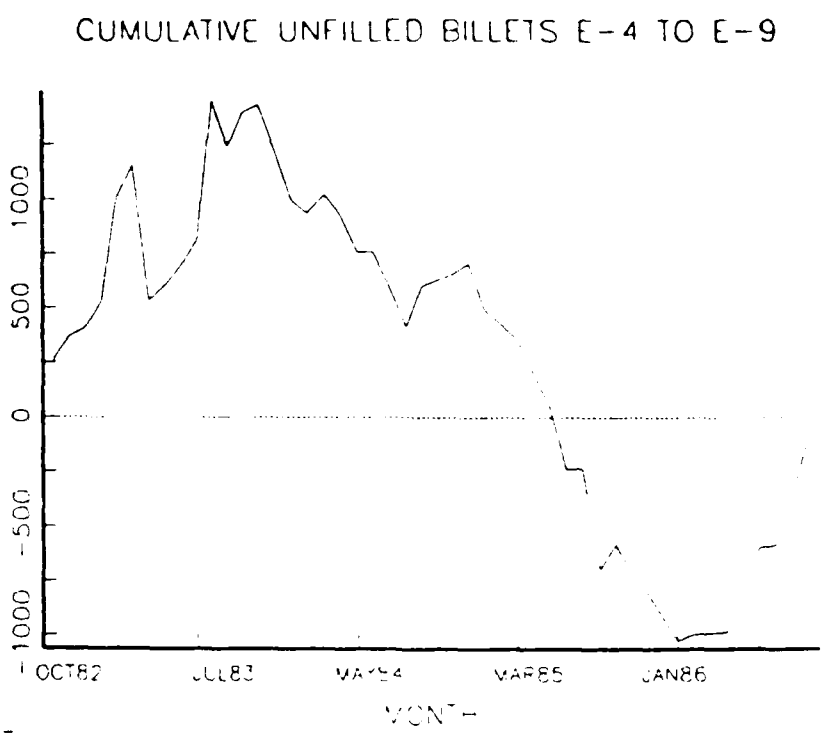

Figure 3.1 : Cumulative Unfilled Billets

3. Model

Our model attempts to reflect the actual process used by the CG to determine the monthly promotions (and consequently the promotion rates). The following equations were developed to estimate the promotion rates.

a. Promotion rates to E-5 through E-9

In order to attempt to capture the previously described promotion process, we calculated the number of vacancies we expect to fill during a month. This will usually be less than the anticipated number of vacancies that will occur because for most paygrades, we expect to leave some portion of the vacancies unfilled. The number of promotions is then calculated as described previously.

As previously mentioned, historical data shows that the number of billets in paygrade i is a proportion of the total force strength. Therefore, the following parameter is defined:

PYR_i = the ratio of billets in paygrade i to the total number of billets.

This parameter is estimated as the ratio of the 1986 monthly average number of billets in paygrade i to the monthly average of the total number of billets. We decided to limit the data to the most recent year to minimize the upward trend of the ratios in several of the paygrades.

Next define

$PCT_i(t)$ = the percentage of the billets available in paygrade i for which we expect to have enough eligible personnel to promote.

This variable attempts to capture the CG's previously described inability to fill all billets. This variable is a function of time. For example, in January and July, when the new lists of personnel eligible for promotion are issued, there is a significant increase in the ability to fill vacancies because at that time the CG may promote as many qualified personnel as possible to fill vacancies. The $PCT_i(t)$ values were estimated as three year averages for 1984 through 1986 for each month t and each paygrade i.

Next, introduce

$N(t)$ = Total stock on the last day of month t

$n_i(t)$ = stock of paygrade i on the last day of month t

for $i = 1,2,\ldots,9$

$n_{i,i+1}(t)$ = number promoted from paygrade i to $i+1$ during the period $(t-1,t)$ for $i = 1,2,\ldots,8$.

Also define

$p_{i,i+1}(t)$ = promotion rate form paygrade i to paygrade $i+1$

$p_{i,i+1}(t)$ is estimated as the number of promotions from paygrade i to $i+1$ divided by the stock of paygrade i at the beginning of period t.

The number of promotions is calculated as follows:

1. First compute the projected number of billets in paygrade i during period t = $PYR_i * N(t)$
2. Next, compute the projected number of billets in paygrade i that will be filled during period t:

$$PCT_i(t) * PYR_i * N(t)$$

3. Finally, the projected number of promotions to paygrade i during period $(t-1,t)$ is :

$$n_{i-1,i}(t) = PCT_i(t) * PYR_i * N(t) + n_{i,i+1}(t) - [n_i(t-1)*(1-w_i(t))]$$

$i=5,6,7,8,9$ $\qquad$ $t=1,2,\ldots,12$ $\qquad$ [3.1]

It is possible for the CG to shrink in total strength so that equation [3.1] would estimate a negative number of promotions because the decline in the estimated number of billets exceeded the estimated number of attritions.

Accordingly, we reflect CG policy by modifying our estimate to be :

$$n^{*}_{i-1,i}(t) = \max [0, n_{i-1,i}(t)]$$

The promotion rate is then estimated by:

$$p_{i-1,i}(t) = n^{*}_{i-1,i}(t) \div n_{i}(t)$$

The results of these estimates are summarized in Table 3.7.a.

TABLE 3.7.a PROMOTION RATES TO E-5 THROUGH E-9

	E-9	E-8	E-7	E-6	E-5
PYR	.010	.0164	.0896	.181	.197
PCT(t) excluding JAN and JUL	1.0	1.0	.998	.949	.886
PCT(Jan)	1.0	1.0	1.0	.960	.900
PCT(Jul)	1.0	1.0	1.0	.960	.900

b. Promotions to paygrade E-4

These promotions are directly tied to the internal policy of A-school scheduling. The factors affecting this policy are complicated and the data seems to indicate that the policy varies considerably. Our proposed estimate of the E-4 promotion rates is based on the observation that there is a large increase in the promotion rate in January and July which we attributed entirely to the policy of promoting all "strikers" from the new advancement list. No other time trends were observed in the data. A one way analysis of variance testing the hypothesis that the monthly promotion rates (1983 - 1986) for all months except January and July are equal indicates that at a significance

level of $\alpha = .05$ we cannot reject the hypothesis that the rates are the same. See Table 3.7.b. Our estimates for all months except January and July will be the average of the other ten months' promotion rates for 1983 - 1986 (40 observations). An examination of the historic "striker" promotions did not reveal any significant trends. We will estimate January and July promotion rates as the four year average of the respective monthly rates for 1983 through 1986.

TABLE 3.7.b ANOVA PROMOTION RATE TO E-4

Source	SS	df	MS	F-ratio
Month (except JAN,JUL)	.0027846	9	3.094E-4	.633
Error	.0146596	30	4.886E-4	
Total	.017442	39		

$\bar{p}_{3,4}$ (all except Jan,July) = .04133

$\bar{p}_{3,4}$(Jan) =.07228

$\bar{p}_{3,4}$(Jul) =.09355

c. Promotions to paygrade E-3

Our hypothesis for the promotion rate to E-3 is that the promotion rates are the same for each month. However, the data appeared to indicate a uniform promotion rate throughout the year with a relatively large increase in July. We could not determine any internal (policy) causes for this increase but we suspect it is somehow related to the

processes already described for the E-4 paygrade. A one-way ANOVA of data indicates that at a significance level of α=.05, we cannot reject the hypothesis that the monthly promotion rates for all months except July are the same. We estimate the E-3 promotion rates as the average of the historic monthly promotion rates for all months except July, over the years 1983-1986. July's promotion rate is estimated using a four year average over the same years.See Table 3.7.c

TABLE 3.7.c ANOVA PROMOTION RATE TO E-3

Source	SS	df	MS	F-ratio
Month (except JUL)	.0071932	10	7.193E-4	.872
Error	.0272204	33	8.2486E-4	
Total	.0344136	43		

$\bar{p}_{2,3}$(all except Jan,July) = .06756

$\bar{p}_{2,3}$(Jul) =.11088

d. Promotions to paygrade E-2

These promotions are the result of successful completions of recruit training. We felt a reasonable model would project the number of promotees based on E-1 accessions lagged two and three months since recruit training is 8 weeks in duration. We examined a linear regression model of the form:

$$n_{1,2}(t) = \beta_0 + \beta_1 r_1(t-2) + \beta_2 r_1(t-3) + \epsilon$$

We found that the number of recruits lagged three months was

a statistically insignificant carrier variable and developed a simple linear regression model using only number of recruits lagged two months. During the diagnostic phase of the regression analysis we decided to exclude four observations (JAN83,OCT83,DEC83,JUL86) as probable outliers among our 48 observations. Our results achieved an R-square value of .59. We felt these results were favorable in light of the problems we had extrapolating the historic promotions to E-2 described in Chapter II. The results of this model are summarized in Table 3.7.d.

TABLE 3.7.d REGRESSION RESULTS FOR PROMOTION TO E-2

$$\beta_0 = 17.39$$

$$\beta_1 = .712428 \qquad (r(t-2))$$

$$R^2 = .588$$

4. Summary

We would note that promotion rates estimated by these methods may seem low when compared to what is generally perceived by DP members as promotion rates. Our promotion rates are proportions of the entire stock in the next lower pay grade, while promotion rates are normally thought of in terms of proportions of those eligible for promotion. We have previously described the lack of data on eligible personnel that prevented us from using this latter definition. The difference will be consistent with the rest of the model to be developed.

IV. MANYEAR CONSUMPTION ALGORITHM

Each fiscal year (1 October--30 September) Congress specifies two personnel growth constraints that are pertinent to the forecasts of attrition rates and force strength. The CG is given an end of year total force strength target and an annual Full Time Equivalent (FTE) target. The FTE target is the cumulative monthly manyear consumption for a fiscal year. More specifically, the FTE (manyears) consumed in a month is defined as 1/12 of the average of the beginning of month stock and the end of month stock. The purpose of the FTE target is to provide some external control of the growth during a year. A graphical representation of the relationship between the FTE target and the monthly stocks should clarify the purpose of this constraint. In Figure 4.1, we can see from the preceding definition that the FTE is equal to twelve times the area bounded by the month axis, the stock axis, the line connecting the monthly stocks and a vertical line at the end of the year.

The algorithm developed in this section will forecast the end of month stocks, N(t), during the fiscal year that will meet both the end of year stock target and the FTE target. It will also provide a solution to meet these targets when the starting point is some end of month during the fiscal year, i.e. given the stocks at sometime at or after 1 October it will provide a solution for the remainder of the year.

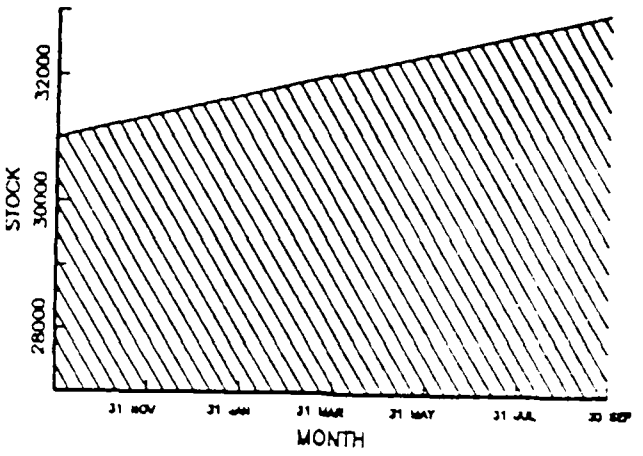

Figure 4.1 : FTE = 12 x Shaded Area Under the Line

An initial examination of the problem revealed that without additional assumptions and constraints, there would be a large number of solutions to any realistic set of targets. Therefore, the following restrictions were developed by examining the processes that influence the current decision making:

1. The change from the beginning of the year to the end of the year should be as linear as possible. This is justified by the need to reduce large changes to the system. Due to the small size of many units, paygrades, ratings, etc. in the CG, a large monthly change in total strength could have an adverse effect on adequate manning of units. Additionally, a large change in the monthly stock would imply a significant change of recruits at the CG training center; this is undesirable, especially if the change results in a large influx of recruits.

2. The number of recruits are fixed at low levels for December (there is an historic inability to recruit at higher levels prior to the holiday season) and June (the CG recruit training center is used primarily for reserve recruit training during the summer months). Using historic data, we arrived at an upper bound of 200 December accessions and 100 June accessions, unless the CG shrinks by more than 3500 during a year, in which case the accessions are fixed at zero for both December and June.
3. Given the above restrictions, we should attempt to preserve linearity for the longest number of months possible. We assume that the changes occuring during any particular month are linear.
4. Historical data shows recruiting efforts are most successful in August, September, October and November. These months provide the most flexibility in meeting quotas.

A. MODEL DESCRIPTION

The problem of formulating an algorithm to determine a unique forecast of the end of month strengths that would meet the restrictions described above was facilitated by examining a graphical representation of the constraints.

We previously mentioned that the CG prefers to change linearly. Ideally, the monthly forecasts of force strength would lie on a line connecting the 1 October stock and the

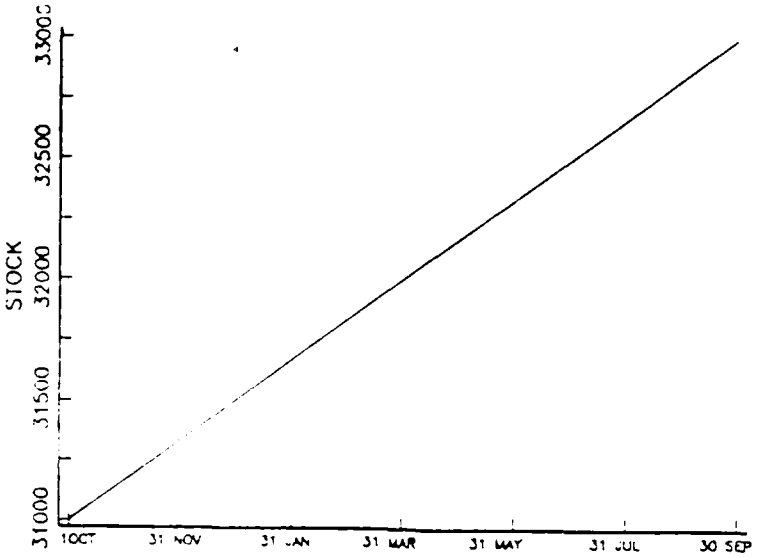

Figure 4.2 : Linear Stock Description

following year's 30 September stock (Figure 4.2). This solution is improbable for the two reasons discussed below.

First, we have previously discussed the limitations on accessions for December and June. As a result, accessions are normally less than attritions and so, stocks decline during those two months. Therefore, in the months of December and June, we see a decline equal to the difference between the estimated attritions and the fixed number of accessions. Otherwise, we can maintain linearity during the rest of the year. The resulting monthly stocks lie on the bold line segments in Figure 4.3.

Secondly, as discussed previously, the FTE constraint may require the CG to change more toward the beginning or, alternatively, the end of the year . The pure linear solution could only provide an FTE equal to the average of the 1 OCT and 30 SEP stocks. The piecewise linear graph we have just described will allow us the flexibility to find at least one

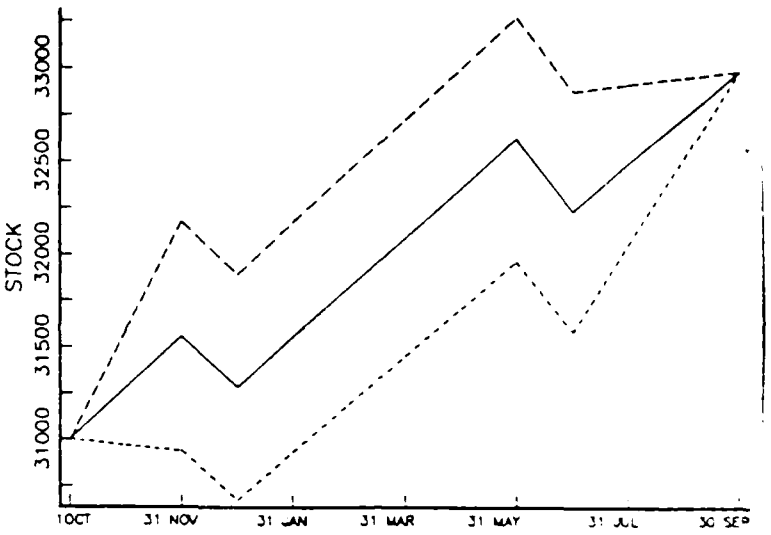

Figure 4.3: Piece-wise Stock Description

one solution that satisfies any FTE constraint by varying the area under the five line segments. The dashed lines in Figure 4.3 demonstrate and example of a larger FTE (greater area under the line segments) and alternatively a smaller FTE. Specific examples may clarify the changes in FTE that are possible with the five line segment description. In Figures 4.4 through 4.6 we are looking at three different five-piece line segments that connect the end of month stock for 30 September (31000) with the 30 September stock (33000)of the following year. Figure 4.4 demonstrates an FTE that is the average of the beginning and ending stocks. This would encourage the CG to grow in a linear manner. Figure 4.5 demonstrates an FTE that is closer to the beginning strength than it is to the ending strength. We can see that this encourages the CG to grow more toward the end of the year than close to the beginning. Figure 4.6 demonstrates an FTE that is closer to the ending strength than it is to the

beginning strength. This encourages the CG to grow more toward the beginning of the year and less toward the end.

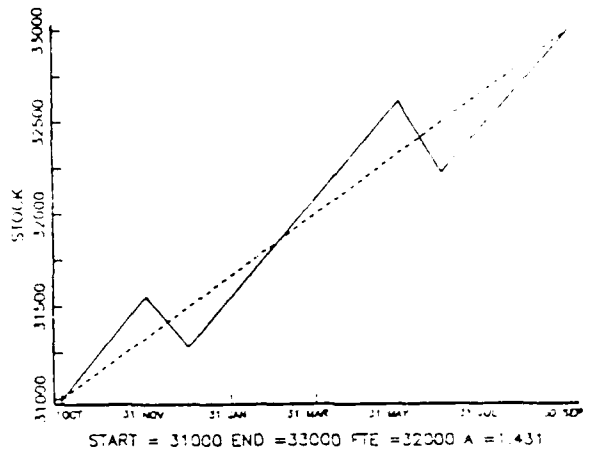

Figure 4.4 : Default

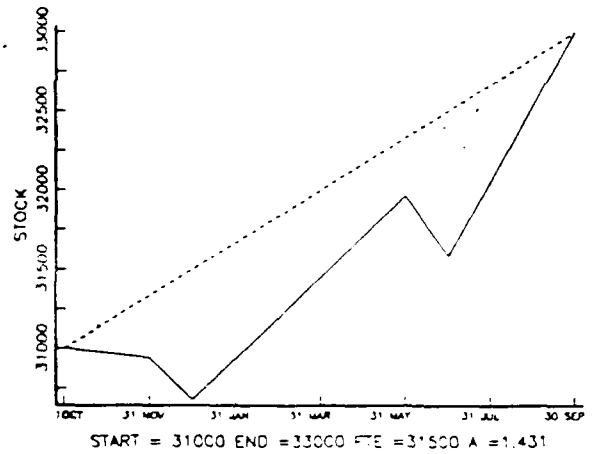

Figure 4.5 : Lower FTE

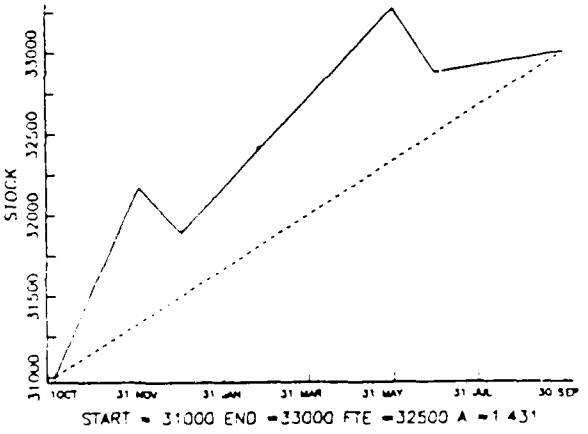

Figure 4.6 : Higher FTE

Similiar graphs can be seen in Figures 4.7 through 4.9 for a situation where the ending strength (31000) is less than the beginning strength (32000).

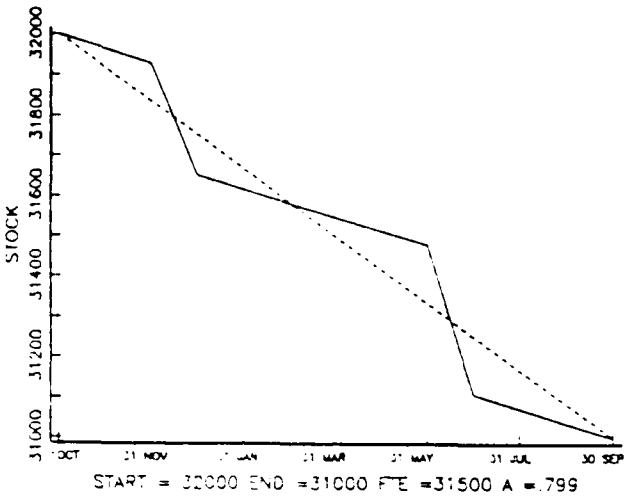

Figure 4.7 : Default

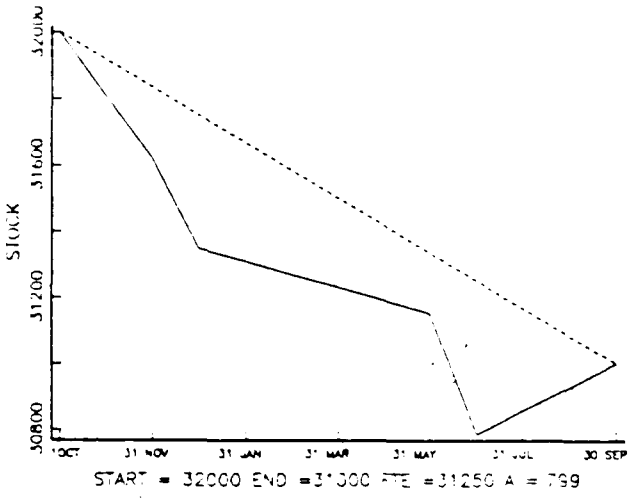

Figure 4.8 : Lower FTE

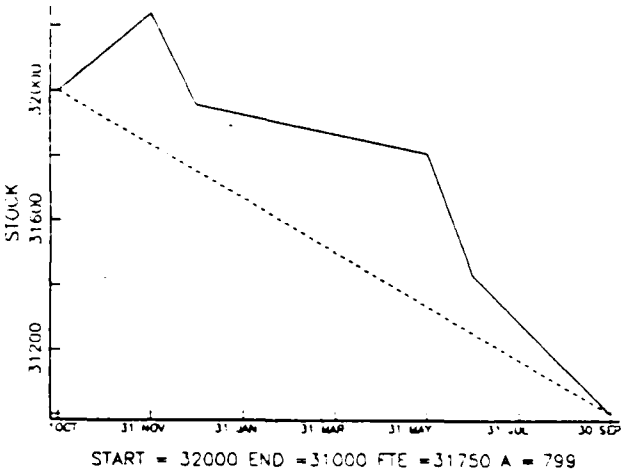

Figure 4.9 : Higher FTE

We previously stated that the area under the described line segments is twelve times FTE. We can see from Figure 4.3 that the only points that are fixed are 1 OCT and 30 SEPT of the following year. We can further see from Figure 4.3 that one way we can derive a combination of equations for the five line segments that satisfies the FTE constraint is to specify the slope of the 31 DEC - 31 MAY line segment. Once the slope of this segment has been fixed, there will be

a unique set of line segments that concurrently satisfy the accession restrictions and the FTE constraint, i.e. the area under the line segments must equal twelve times FTE. We can subsequently describe a unique equation for the area under the line segments in terms of the monthly stocks.

We can now specifically describe the equation of each line segment in the general form $y = mx + b$. We will initially describe separately each line segment. Later we will tie together the five line segments through their common points. First, we describe the slope of the 31 DEC -31 MAY line segment in relationship to the slope of the 1 OCT - 30 SEP line (the ideal linear case). The slope of the 1 OCT-30 SEP line will be called DEL. The slope of the 31 DEC - 31 MAY line segment will be described by the multiplier (A) times DEL. The introduction of the multiplier A and the reference to the line 1 OCT - 30 SEP slope (DEL) will be important to modifications to the algorithm described later because the DS may want to change A to control the monthly rate of change in stocks. The multiplier A will allow us to change the slope of the 31 DEC - 31 MAY line segment by increasing or decreasing A. We will also know if the slope of the 31 DEC - 31 MAY line segment is more or less steep than the slope of the ideal 1 OCT - 30 September line. We know that $0 \leq A < \infty$ and therefore, an $A > 1$ increases the steepness of the slope and an $A < 1$ decreases the steepness of the slope.

In order to describe each monthly stock in Figure 4.3 we first need to define the following variables:

Let t refer to the end of the month, namely:

t=0	means 30 SEP	t=7	means 30 APR
t=1	means 31 OCT	t=8	means 31 MAY
t=2	means 30 NOV	t=9	means 30 JUN
t=3	means 31 DEC	t=10	means 31 JUL
t=4	means 31 JAN	t=11	means 31 AUG
t=5	means 28 FEB	t=12	means 30 SEP
t=6	means 31 MAR		(following year)

Further,

FTE = The manyear consumption specified

N(t) = Total strength at time t

N(0) = Total initial strength (given)

N(12) = 30 September Stock (given), i.e. total end year strength

WJ = 1/(1-June attrition rate)

WD = 1/(1-December attrition rate)

RD = December recruits, fixed as described above

RJ = June recruits, fixed as described above

DEL = (N(12) - N(0))/12 : slope of line segment connecting beginning and ending stock. The algorithm developed in this section requires that DEL not equal 0. From a practical standpoint, this means a difference between the beginning and ending stock of at least one. For all practical purposes, this will have no effect on the end results.

A = the slope multiplier

Each line segment in Figure 4.3 is now described in Table 4.1.

TABLE 4.1: STOCK FORMULAS

N(11) = N(11)	N(5) = N(8) - 3A*DEL
N(10) = 2N(11)-N(12)	N(4) = N(8) - 4A*DEL
N(9) = 3N(11)-2N(12)	N(3) = N(8) - 5A*DEL
N(8) = WJ*N(9)-WJ*RJ	N(2) = N(3)*WD - WD*RD
N(7) = N(8) - A*DEL	N(1) = .5N(2)+.5N(2)
N(6) = N(8) - 2A*DEL	

We next formulate the equation for the area under the line segments and solve for each of the monthly stocks. This is an uncomplicated but tedious procedure because of the numerous variables so we will solve the problem in three parts.

1. Part 1

Part 1 is a solution for the model starting 1 OCT. All stocks will be referenced to the 31 August stock, N(11). August was selected to simplify the solution to part 3 (mid period solutions). The multiplier A used in this part may be modified by the desires of the DS to regulate the growth rate. We will provide a default solution for the multiplier (A) in part 2.

2. Part 2

Part 2 is a solution for the multiplier A to optimize the model. Optimization will be defined as the

least squares solution which minimizes the difference between the solution's stocks (as shown in Figure 4.3) and stocks which would result from a straight line between the current month's stocks and the 30 SEP stock target.

3. Part 3

Part 3 is a solution for the problem starting at any point in the year. Through the use of binary variables and minor modifications to the assumptions described previously, we begin our forecasts sometime after 1 OCT and will project new stocks for the remainder of the year to meet the original constraints.

B. SOLUTIONS

1. Part 1 Full Year Model

The objective here is to find the end of month strengths, N(t), for all t = 1,2,...,11 that will meet the constraints described previously in this chapter.

The first step is to describe each end of month stock ,N(t), from Table 4.1 in terms of the 31 AUG stock, N(11). The results are summarized in Table 4.2.

Next, in order to solve for N(11) we write the equation for the area under the line segments as:

$$24FTE = N(0) + N(12) + 2\sum_{t=1}^{11} N(t) \qquad [4.1]$$

TABLE 4.2: MODIFIED STOCK FORMULAS

$N(11) = N(11)$

$N(10) = 2N(11)-N(12)$

$N(9) = 3N(11)-2N(12)$

$N(8) = WJ*[3N(11)-2N(12)-RJ]$

$N(7) = WJ*[3N(11)-2N(12)-RJ]-A*DEL$

$N(6) = WJ*[3N(11)-2N(12)-RJ]-2A*DEL$

$N(5) = WJ*[3N(11)-2N(12)-RJ]-3A*DEL$

$N(4) = WJ*[3N(11)-2N(12)-RJ]-4A*DEL$

$N(3) = WJ*[3N(11)-2N(12)-RJ]-5A*DEL$

$N(2) = WJ*WD*[3N(11)-2N(12)-RJ]- WD*[5A*DEL +RD]$

$N(1) = .5(N(0)+WJ*WD*[3N(11)-2N(12)-RJ] - WD*[5A*DEL +RD])$

We then make the substitutions in [4.1] for each N(t) given in Table 4.2. The resulting equation is then expressed in terms of N(11) and solved for N(11) to obtain:

$$N(11) = [NUM1 + A*NUM2] \div DEN \qquad [4.2]$$

where, for notational simplification,

$NUM1 = 24FTE-2N(0)+N(12)*[3+24WJ+6WJ*WD]+3[WD*RD+WJ*RJ*(WD+4)]$

$NUM2 = 15DEL*(3+WD)$ and $DEN = 12+9WJ*(4+WD)$

The remaining N(t)s are solved by back substituting the result [4.2] for N(11) into Table 4.2.

2. Part 2. Determining the optimal multiplier (A).

The optimal multiplier A is defined as that number which provides the least squares solution minimizing the vertical distance between the projected stocks and the stocks lying on a line between the starting stock and ending stock. This measure of effectiveness was suggested by the CG's desire to remain as close to the 1 OCT - 30 SEP line as possible. We define the following additional variables:

Let P(t) be the stock for month t lying on the line segment connecting N(0) and N(12), i.e.

$$P(t) = N(0) + [DEL*t] \qquad t=1,2,\ldots,11 \qquad [4.3]$$

Let D(t) be the derivative with respect to A of N(t), i.e.

$$D(t) = \frac{\delta N(t)}{\delta A}$$

Then from Equation [4.2] and Table 4.2,

$$\begin{aligned}
D(11) &= NUM2/DEN \\
D(10) &= 2*NUM2/DEN \\
D(9) &= 3*NUM2/DEN \\
D(8) &= 3*NUM2*WJ/DEN \\
D(7) &= 3*NUM2*WJ/DEN - DEL \\
D(6) &= 3*NUM2*WJ/DEN -2*DEL \qquad [4.4] \\
D(5) &= 3*NUM2*WJ/DEN -3*DEL \\
D(4) &= 3*NUM2*WJ/DEN -4*DEL \\
D(3) &= 3*NUM2*WJ/DEN -5*DEL \\
D(2) &= 3*NUM2*WJ*WD/DEN -5*WD*DEL \\
D(1) &= 1.5*NUM2*WJ*WD/DEN -2.5*WD*DEL
\end{aligned}$$

The optimal multiplier A was defined as the value of A which minimized the sum of squares of the vertical distance between N(t) and P(t). We can solve the equation resulting by taking the first derivative of the sum of squares set equal to zero to obtain the optimal value of A:

$$\frac{\delta}{\delta A} \sum_{t=1}^{11} (N(t) - P(t))^2 = 0 \qquad [4.5]$$

Taking the derivative with respect to A we obtain:

$$2 * \sum_{t=1}^{11} \{ [N(t) - P(t)] * D(t) \} = 0 \qquad [4.6]$$

Substituting equations [4.3], [4.4] and the values in Table 4.2 into equation [4.6], we can solve for A.

$$A_{opt} = \frac{\sum_{t=1}^{11} D(t)*P(t) + [NUMA*K3] + [NUMB*K1] + [N(12)*K4] - [(NUM1/DEN)*K5]}{[DENA*K3] + [DENB*K1] + [(NUM2/DEN)*K5] - DENC} \qquad [4.7]$$

where for notational simplification:

$$K1 = D(2) + .5D(1)$$

$$K2 = .5N(0)*D(1)$$

$$K3 = \sum_{t=3}^{8} D(t)$$

$$K4 = D(10) + 2D(9)$$

$$K5 = D(11) + 2D(10) + 3D(9)$$

$$NUMA = WJ*[2*N(12) + RJ - (3*NUM1/DEN)]$$

$$NUMB = WD*\{[2WJ*N(12)] + [WJ*RJ] + RD - [3WJ*NUM1/DEN]\}$$

$$DENA = 3WJ*NUM2/DEN$$

$$DENB = WD*[(3WJ*NUM2/DEN) - 5DEL]$$

$$DENC = \sum_{t=3}^{8} (8-t)*DEL*D(t)$$

Taking the second derivative with respect to A of equation [4.5] to see if our solution is a minimum and making the same substitutions that led to equation [4.6] we obtain

$$\frac{\delta^2}{\delta A^2} \sum_{t=1}^{11} [N(t) - P(t)]^2 = 2*\sum_{t=1}^{11} D^2(t) + [N(t) - P(t)]*D_2(t) \qquad [4.8]$$

where we have defined $D_2(t) = \frac{\delta^2 N(t)}{\delta A^2}$

But if we examine the results of equations [4.4] we see that the first derivatives, D(t), are not functions of A for any value of t and therefore the second derivatives, $D_2(t)$ are always zero. Equation [4.8] reduces to

$$\frac{\delta^2}{\delta A^2} \sum_{t=1}^{11} [N(t) - P(t)]^2 = 2*\sum_{t=1}^{11} D^2(t)$$

Therefore, since we previously stated that DEL is never equal to zero, the second derivative is always greater than zero. Therefore our solution for the optimal multiplier A is a minimum of the least squares equation.

3. Part 3, Partial Year Model

The essence of the solutions to the various cases of the partial year model described below is the binary variable Z(t) which turns the months prior to t off when calculating the partial year cases.

The following variable modifications and additions will apply to all cases of this variation of the model:

k = starting month $k = 1,2,\ldots 12$

FTE = The annual manyear consumption constraint

FTE_k = The manyears left to consume between month k and the end of the year

$$= FTE - \sum_{t=1}^{k} [N(t-1) + N(t)]/24 \qquad [4.1.a]$$

The binary month switch variable is

$$Z_k(t) = \begin{cases} 1 & \text{for } t > k \\ 0 & \text{otherwise} \end{cases}$$

$$DEL = [N(12)-N(k)] / (12-k)$$

The points on the line connecting beginning and ending stocks, N(k) and N(12), are

$$P(t) = N(k) + [(t - k)/(12 - k)]*DEL , \quad t=k+1,\ldots,12$$

If we substitute $Z_k(t) * N(t)$ for $N(t)$ in equation [4.1.a], and make the same substitutions we made to arrive at equation [4.2] we obtain:

$$N(11) = (NUM1 + A*NUM2)/DEN \qquad [4.2.a]$$

where we now redefine

$$NUM1 = 24\ FTE_k + (WD*(WJ*RJ+[2WJ*N(12)]+RD)*[2Z_k(1)+Z_k(2)]) +$$

$$([4WJ*N(12)+2WJ*RJ]*\sum_{t=1}^{3} Z_k(t))-([1+Z_k(1)]*N(0))+(N(12)*[2Z_k(10)+4Z_k(9)-1])$$

$$NUM2 = 2DEL *(\sum_{t=3}^{8} [8-t]Z_k(t))+ (5WD*DEL[2Z_k(1)+Z_k(2)])$$

$$DEN = 2+4Z_k(10)+6Z_k(9)+\{6*WJ*\sum_{t=3}^{8} Z_k(t)\}+\{3*WJ*WD[2Z_k(1)+Z_k(2)]\}$$

An examination of the equations and graphical representation in Figure 4.3 reveals that there are three different cases possible when forecasting stocks after 31 October.

a. Eleven month case (k=1)

We need to forecast stocks for 30 NOV through 30 SEP using 31 October data. This case will be an abbreviated version of the part 1 model and will forecast N(2) through N(11).

The optimal multiplier A is calculated as in equation [4.5] by substituting $D(t)*Z_1(t)$ for D(t).

We solve equation [4.2.a] for N(11) where k=1 and, by substituting N(11) into the equations in Table 4.2 and finally modifying the stocks by substituting

$$N(t) = N(t)*Z_1(t)$$

we obtain the forecast stocks N(t), t= 2,3,...11.

b. Ten month through five month case (k = 2,3,...,7)

We need to forecast stocks for the remainder of the fiscal year, beginning with any month between 30 November and 30 April. This model is also a modification of the part 1 model. The difference is that there is one and only one slope of the 31 DEC - 31 MAY line segment that allows the FTE

constraint to be satisfied and therefore there will be only 1 multiplier (A) possible. See Figure 4.10.

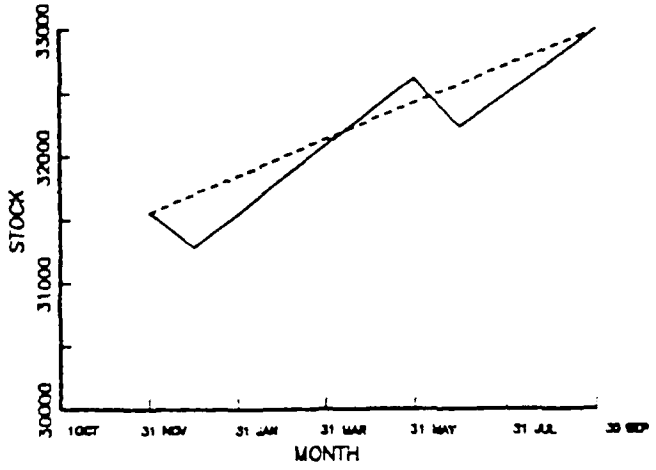

Figure 4.10 : Ten to five month case

In this case we forecast N(k+1) through N(11) where k = 2,3,4,5,6, or 7. Define the following variables:

C1 = 1 if k < 4, = 4-k otherwise

C2 = 2 if k < 4, = 5-k otherwise

C3 = 3 if k < 4, = 6-k otherwise

C4 = 4 if k < 4, = 7-k otherwise

C5 = 5 if k < 4, = 8-k otherwise

The following are the modified equations to account for the abbreviation of the forecasting model:

N(3) = N(3) - Z(3)*[WD*Y(0)-RD]

N(4) = N(3) +C1*A*DEL

N(5) = N(3) +C2*A*DEL

N(6) = N(3) +C3*A*DEL

N(7) = N(3) +C4*A*DEL

N(8) = N(3) +C5*A*DEL

$$N(9) = [1-WJ]N(8) + RJ$$

$$N(10) = 1/3[2N(9) + N(12)]$$

$$N(11) = 1/3[N(9) + 2N(12)]$$

We can substitute the above equations into equation [4.6] and solve for the multiplier λ in the same way we solved equation [4.7]. The result is:

$$\lambda = \frac{24FTE_k - 3N(12) - 4RJ - N(0) - \lambda\left(\sum_{t=3}^{7} Z_k(t) + 3 - 2WJ\right) * (N(0) - Z_k(3) * [WD * N(0) - RD])}{[Z_k(4) * C1] + [Z_k(5) * C2] + [Z_k(6) * C3] + [Z_k(7) * C4] + [(3-2WJ) * Z_k(8) * C5]}$$

[4.10]

We can now solve for N(t) by using the appropriate equations described above . We can eliminate months prior to the current month k by modifying the forecasts, using $N(t) * Z_k(t)$ in place of N(t).

c. Four month through one month case (k= 8,9,10,11)

We need to forecast end of month stocks beginning at any period after 31 MAY. See Figure 4.11. We will ignore the FTE constraint in this portion of the model. Relaxing the FTE constraint makes sense because at this late date, our forecasts will have little impact on policy changes that would be necessary to make significant shifts in the growth patterns. A method to include FTE is discussed in Chapter VI.

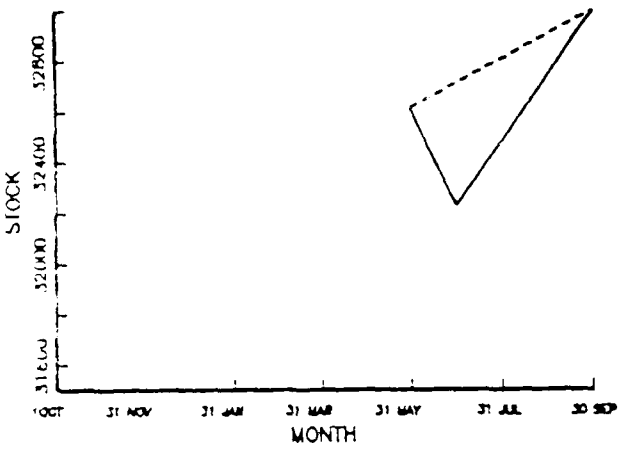

Figure 4.11 : Four month case

This case is used to forecast N(k+1) through N(11) where k = 8,9,10,11 . The solutions are simply applications of the general equation y = mx + b, with

N(9) = N(8)*[1/WJ]+ RJ for k = 8

N(10) = [2/3]*N(9) + [1/3]*N(12) for k = 8 or 9

N(11) = [1/3]*N(9) + [2/3]*N(12) for k = 8 or 9

N(11) = [.5*N(10)] + [.5*N(12)] for k = 10

C. EXAMPLES

We previously described the output of our model for various FTE constraints in Figures 4.4 through 4.9. Additionally, we can see the effect of changing the multiplier A from the default value calculated above.

1. Growth example

In Figure 4.12, the default value of the multiplier A is 1.431. In Figure 4.13, the value of A is lowered to .75. This causes more rapid growth at the beginning of the year.

A value of A higher than the default in this example would have caused more rapid growth at the end of the year.

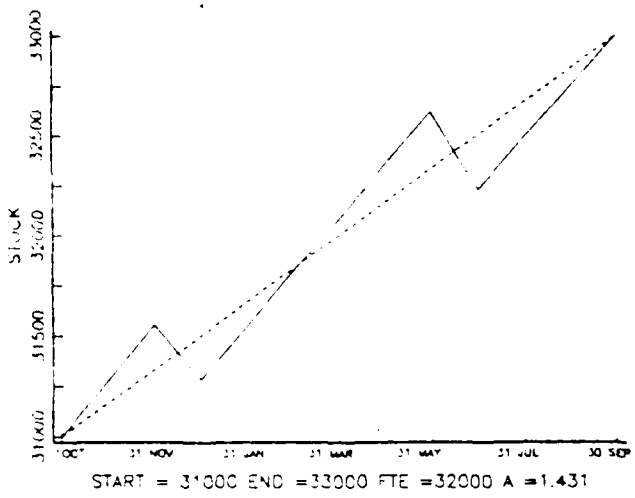

Figure 4.12 : Default A

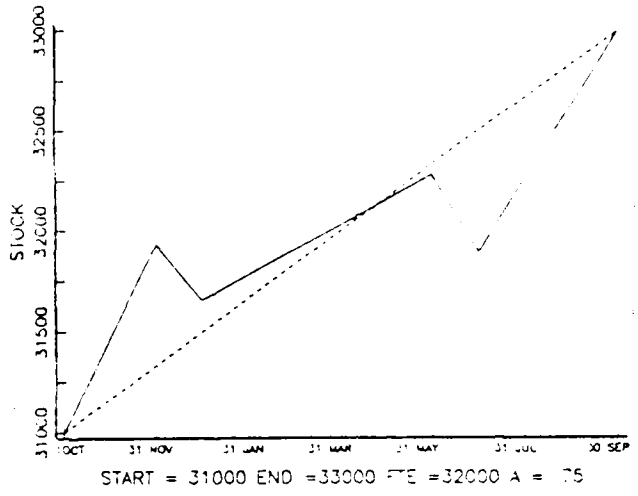

Figure 4.13 : Lower A

2. Shrinkage example

In Figure 4.14, the default value of the multiplier A is .8. In Figure 4.15 the value of A is raised to 1.5. This causes a more rapid decline at the end of the year. Similiarly, a lower value of A would have caused a more rapid decline at the beginning of the year.

We can use the changes obtained by modifying the multiplier A to include the effect of anticipated changes in the recruiting environment, i.e. the CG may want to change the multiplier A to capitilize on good recruiting months.

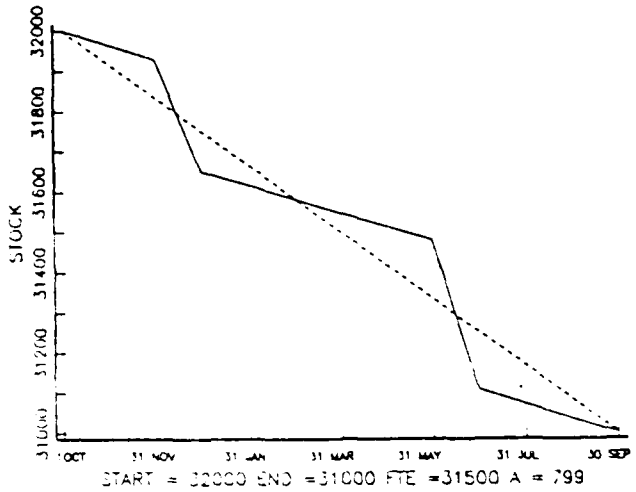

Figure 4.14 : Default A

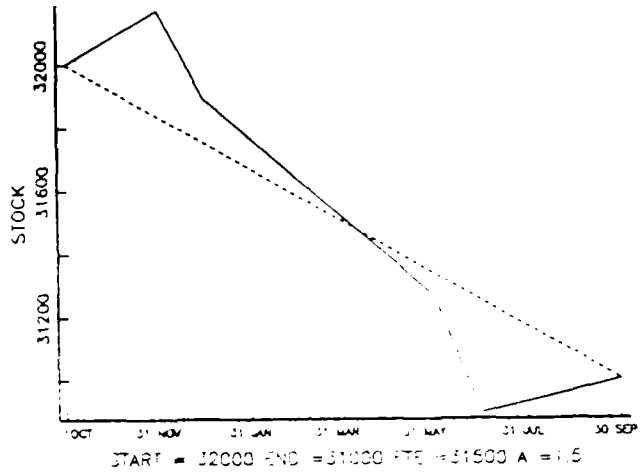

Figure 4.15 : Higher A

The algorithm will always provide a solution at the beginning of the year when FTE > 0. Clearly, the solution may violate other constraints such as the upper bound on monthly recruits and mid-year calculations may not have a feasible solution to the FTE constraint. The algorithm will provide feasible solutions to historically typical data. Other atypical situations and possible alterations to the solution will be discussed in chapter VI.

Lastly, it is possible that the CG would want to explore the effect of ignoring the FTE constraint. The most practical implementation of this decision would be to use the model as developed and input an FTE constraint that is the average of the beginning and ending stock. The effect of this FTE would be to approximate a straight line.

V. MARKOV TRANSITION MODEL

We have chosen to consolidate the personnel movements described in Chapter III into a modified Markov transition model as described by Bartholomew and Forbes [Ref. 2:pp. 85-100]. This model was chosen because it seemed to most closely reflect the type of system the CG has and for which we had complete data. The CG has a hierarchical paygrade structure and personnel flows consisting solely of accessions, attritions and promotions to the next higher paygrade [Ref. 2:pp. 85-87]. However, the following modifications to the standard Markov transition model are needed:

1. The CG personnel flow rates are non-homogenous (they differ from month to month).
2. There are constraints on the number of accessions per month. As described in Chapter IV, December and June accessions have an upper bound of 200 and 100 respectively, and a lower bound of zero. The remaining months have an upper bound of 720 and a lower bound of 150.
3. The number of E-8 and E-9's is limited by law to two percent and one percent of the total force strength respectively.
4. The 30 September total force strengths are specified .
5. The rate at which the CG changes is regulated by the man year consumption constraint (FTE) set by law.

These modifications , except the accession limits for all months other than December and June, have been explicitly integrated into the forecasts of personnel flows developed in the preceding two chapters:

1. The personnel flow rates discussed in Chapter III were developed as a function of the time of year.
2. The December and June accession constraints were incorporated into the total force projections developed in Chapter IV.
3. The E-8 and E-9 stock constraints were incorporated into the promotion rates developed in Chapter III through the use of the PYR variable.
4. The 30 September stock and the FTE constraint are incorporated in the force projections developed in Chapter III.

We have decided not to explicitly incorporate the accession limits for any months except December and June because they are not operative when the system is within its historically typical bounds. In Chapter VI we will describe a method to modify the model in circumstances outside of the typical operating bounds.

The Markov transition model states that, on the average [Ref. 2:pp.7-8], the stock for paygrade i at the end of month t, is equal to the number of paygrade i personnel staying during month t, $[1 - p_{i,i+1}(t) - w_i(t)] * n_i(t-1)$, plus the number promoted to paygrade i from paygrade i-1

during the same month, $[p_{i-1,i}(t) * n_{i-1}(t-1)]$, plus the accessions into paygrade i during the same month, $r_i(t)$. The notation used in the Markov transition model has been developed and described previously. It is repeated here briefly:

$n_i(t)$ = the stock of paygrade i on the last day of month t

$p_{i,i+1}(t)$ = the promotion rate from paygrade i to paygrade i+1 .

$w_i(t)$ = the attrition rate from paygrade i during month t

$r_i(t)$ = the number of accessions to paygrade i during month t

Therefore, the Markov transition model results in the following equations to forecast the stock of paygrade i at the end of month t:

$$n_i(t) = n_i(t-1)*[1-p_{i,i+1}(t)-w_i(t)] + n_i(t-1)*p_{i-1,i}(t)+ r_i(t)$$

$$i= 2,3,4,5,6,7,8$$

and

$$n_1(t) = n_1(t-1)*[1-p_{1,2}(t)-w_1(t)] +r_1(t)$$

$$n_9(t) = n_9(t-1)*[1 - w_9(t)] + n_9(t-1)*p_{8,9}(t) +r_9(t)$$

Figure 5.1 is an example of the results of our model programmed on a standard spreadsheet. This example starts with a stock of 29953 and the total strength goal at the end of the fiscal year. The FYE goal is 31000 (the last number in the row labeled 1 October column of numbers labeled 1 October vector , n(0). The promotion

AD-A186 673 A PERSONNEL FLOW MODEL FOR PREDICTING THE COAST GUARD ENLISTED FORCE STRUCTURE(U) NAVAL POSTGRADUATE SCHOOL MONTEREY CA L L BARDO SEP 87 2/2

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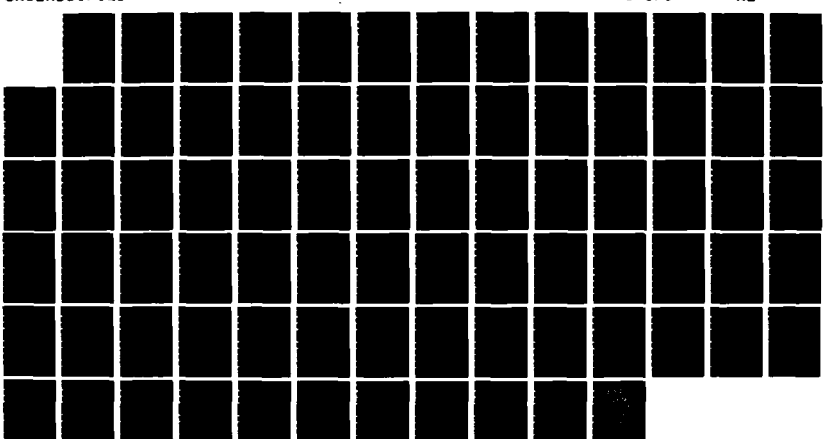
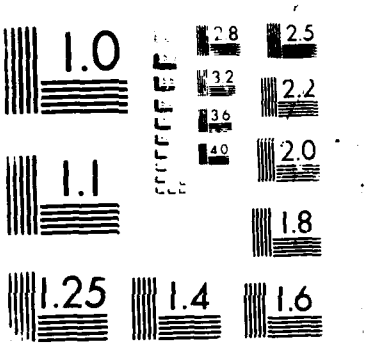




recruitment vector and the total stocks were calculated as described in Chapters III and IV. Each subsequent month's column is the forecast stocks, n(t), as of the last day of the month.

PROJECTED RESULT FOR FISCAL YEAR 1987

PAY GRADE	: OCT	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
E-9	300	302	305	305	307	309	311	313	315	315	315	316	318
E-8	506	508	513	513	515	519	523	526	530	530	530	531	534
E-7	2756	2752	2765	2765	2792	2900	2820	2839	2859	2859	2862	2865	3890
E-6	5410	5414	5452	5456	5540	5530	5559	5597	5636	5640	5726	5724	5708
E-5	5455	5465	5420	5430	5717	5727	5686	5637	5592	5602	5861	5871	5831
E-4	7515	7543	7611	7671	7476	7501	7521	7542	7561	7579	7448	7430	7427
E-3	4286	4153	4020	3911	3697	3649	3593	3550	3525	3513	3507	3501	3476
E-2	2892	2734	2931	3278	3447	3271	3400	3615	3783	3927	3848	3558	3733
E-1	833	1361	1495	1140	1192	1591	1698	1706	1738	1331	1359	1819	1818
TOTAL	29953	30232	30511	30469	30683	30897	31111	31325	31539	31295	31455	31615	31775
FTE		2507.	2530.	2540.	2548.	2565.	2583.	2601.	2619.	2618.	2614.	2627.	2641.
CUM FTE		2507.	5038.	7579.	10127	12693	15277	17878	20498	23116	25730	28358	31000
RECRT		856	658	200	601	741	707	699	692	100	708	804	686
CUM RECRT		856	1514	1714	2315	3056	3763	4462	5154	5254	5962	6766	7452

Figure 5.1: Sample Spreadsheet Results

Figure 5.2 is another example where total strength begins with 29953 and then shrinks to 29000 at the end of the fiscal year. The FTE constraint used was 29500.

PROJECTED RESULT FOR FISCAL YEAR 1987

PAY GRADE	1 OCT	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
E-9	300	300	300	300	300	300	300	300	300	300	300	300	300
E-8	506	506	506	506	506	506	506	506	506	506	506	506	506
E-7	2756	2756	2756	2756	2756	2756	2756	2756	2756	2756	2756	2756	2756
E-6	5410	5414	5418	5422	5426	5430	5434	5438	5442	5446	5450	5454	5458
E-5	5455	5465	5475	5485	5531	5541	5551	5561	5571	5581	5591	5601	5611
E-4	7515	7543	7611	7671	7828	7847	7859	7872	7887	7894	8072	8030	8003
E-3	4286	4153	4020	3911	3679	3599	3517	3441	3374	3315	3220	3167	3106
E-2	2892	2734	2931	3020	2953	2835	2824	2870	2915	2950	2816	2637	2732
E-1	333	999	770	680	699	801	900	735	660	443	416	613	528
TOTAL	29953	29870	29787	29750	29682	29614	29546	29478	29410	29190	29127	29063	29000
FTE		2492.	2485.	2480.	2476.	2470.	2465.	2459.	2453.	2441.	2429.	2424.	2419.
CUM FTE		2492.	4978.	7459.	9935.	12406	14871	17330	19784	22226	24656	27080	29500
RECRT		494	295	200	339	418	423	416	398	100	458	486	430
CUM RECRT		494	789	989	1328	1746	2169	2585	2983	3083	3541	4027	4457

Figure 5.2: Sample Spreadsheet Results

VI. MODEL IMPLEMENTATION

A. IMPLEMENTATION

The estimations described in Chapter III, the forecasts developed in Chapter IV, and the modified Markov model described in Chapter V were merged into a comprehensive Military Employment Capability Plan (MECP) model and programmed on a computer spreadsheet. This programming environment was chosen because it is widely used and accepted in the Coast Guard. Additionally, it has the advantage of allowing direct modification of most of the model parameters and the spreadsheet formulas directly parallel the equations developed in the previous three chapters, allowing easy maintainability of the model.

The MECP model is deterministic and hinges on the point estimates of the attrition rates, promotion rates and expected recruits developed in Chapter III. Various assumptions about the model constraints have been discussed in the previous three chapters. Programming in a spreadsheet allows a user to explicitly change constraints and previously calculated values. This provides an easy method to analyze the effect on accession needs and force structure of the uncertainty inherent in the value of point estimates and our assumptions. In short, the decision maker can utilize the model to explore the effect of several combinations of "what if" situations. The purpose of

this chapter is to describe the major effects of changing some of the key estimates, constraints, and variables on the accession and force structure forecasts. The remaining discussion in this chapter will focus on modifications to the model in light of the spreadsheet implementation. Appendix D contains specific directions for use of the MECP model and also describes the detailed entries needed to obtain the basic results of the model.

B. REASONS TO CHANGE THE MODEL PARAMETERS

There are four major reasons that temporary changes to the model parameters may be considered.

1. External Policy Changes

The legislated constraints (end of year strength and FTE) may change during the year as programs are added or deleted from the CG's missions. Other legislation might indirectly influence the model parameters, for example, a mandated pay raise without additional payroll funding might influence the rate of growth during the year.

2. Internal Policy Changes

The CG periodically changes internal policies with regard to length of enlistments and contract extensions, retirement policies, promotion policies and the shape of the force pyramid. The exact effect of some of these changes is frequently unknown due to a lack of historical data. The decision maker may, however, want to examine the effect on the force structure and accession needs resulting from a

particular policy change, for example, an anticipated ten percent increase in attritions.

3. Infeasibilities

Infeasibilities can be observed in two ways in the MECP model. First, negative recruits and negative stocks in paygrades E-1 and higher are possible when a large shrinkage is called for, indicating that the change called for requires a change in the promotion and/or attrition parameters. Secondly, when "ERR" appears in one or more cells, this indicates that a mathematical solution is impossible. This condition may occur in a full year model if the FTE is less than 1/24 of the sum of N(0) and N(12); and in a partial year model if the FTE consumed to date exceeds the FTE constraint or if the multiplier A specified is other than the calculated value.

4. Adverse Results

The model produces good results when the change during a year does not exceed three percent. When the changes approach ten percent, major changes in the attrition rates and/or promotion rates should probably be made. The need for changes will be obvious when the stocks in a particular paygrade (especially E-4) are examined. There will usually be a clear upward or downward trend in stocks that will be unsatisfactory in the context of the rest of the model. The major parameters used to modify the results are promotion rates, the billet pyramid and the FTE constraint.

C. MAJOR PARAMETERS AFFECTING THE MECP MODEL

1. Attrition Rates.

Increased attrition rates may be needed to cope with a decrease in force size greater than five percent. Figure 6.1.a is an example where the total force strength declines from 29953 to 25000 (16.5 percent). The negative numbers in the recruit row indicate an infeasibility (accessions cannot be negative). The negative E-1 stocks are a direct result of the negative accessions. To correct this problem, we recall from Chapter III that accessions are calculated as:

$$R(t) = N(t) - \sum_{i=1}^{9} [1 - W_i(t-1)]*n_i(t-1)$$

and consequently a negative R(t) can be corrected by increasing a combination of the attrition rates , $W_i(t)$.

Figure 6.1.b is the same scenario as Figure 6.1.a, except the E-5 through E-9 attrition rates have been increased 15 percent, the E-1 through E-4 attrition rates have been increased 25 percent and the promotion rate to E-4 has been decreased 30 percent. The modified attritions rates accommodate the large shrinkage called for, without the need for negative accessions.

The CG may increase attrition by implementing internal policies such as allowing discharges prior to the normal expiration of enlistment, or for below average performers. The MECP model may give an idea of how much the attrition needs to increase to achieve the desired end strength.

PAY GRADE	1 OCT	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
E-9	300	295	291	288	285	281	277	272	267	263	259	254	250
E-8	506	497	491	486	482	477	472	467	463	458	448	437	428
E-7	2756	2752	2747	2743	2740	2735	2728	2719	2712	2704	2695	2683	2673
E-6	5410	5376	5351	5330	5306	5280	5254	5229	5202	5173	5140	5106	5078
E-5	5455	5409	5375	5347	5367	5323	5274	5220	5170	5124	5067	5006	4947
E-4	7515	7503	7534	7578	7549	7548	7541	7534	7530	7517	7480	7425	7382
E-3	4286	4175	4110	4085	4027	3934	3832	3729	3620	3504	3432	3290	3146
E-2	2892	2721	3003	2868	2553	2311	2048	1863	1695	1528	1288	1177	1092
E-1	833	783	166	89	68	51	76	32	-31	40	64	68	4
TOTAL	29953	29510	29068	28814	28376	27939	27502	27065	26628	26309	25872	25436	25000
FTE		2477.	2440.7	2411.	2382.	2346.	2310.	2273.	2237.	2205.	2174.	2137.	2101.
CUM FTE		2477.	4918.4	7330.	9713.	12059	14369	16643	18880	21086	23260	25398	27500
RECRT		144	-64	0	-50	8	6	-12	-37	0	15	28	-26
CUM RECRT		144	80	80	30	38	44	32	-5	-5	10	38	12

Figure 6.1.a : Sample Infeasible Results

PAY GRADE	1 OCT	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
E-9	300	295	291	288	285	281	276	271	266	263	259	254	250
E-8	506	495	488	482	478	473	468	463	458	449	439	426	415
E-7	2756	2751	2746	2741	2738	2732	2724	2714	2706	2697	2687	2673	2662
E-6	5410	5370	5341	5317	5290	5260	5230	5201	5171	5138	5100	5061	5030
E-5	5455	5402	5363	5331	5367	5316	5259	5197	5139	5087	5022	4952	4885
E-4	7515	7468	7474	7497	7421	7388	7348	7310	7276	7232	7160	7069	6994
E-3	4286	4130	4035	3985	3906	3792	3669	3554	3439	3322	3264	3114	2983
E-2	2892	2693	2959	2917	2646	2372	2165	2047	1946	1838	1632	1473	1449
E-1	833	807	371	256	246	326	363	308	227	283	319	214	332
TOTAL	29953	29510	28966	28814	28376	27939	27502	27065	26628	26309	25872	25436	25000
FTE		2477.	2440.7	2411.	2382.	2346.	2310.	2273.	2237.	2205.	2174.	2137.	2101.
CUM FTE		2477.	4918.4	7330.	9713.	12059	14369	16643	18880	21086	23260	25398	27500
RECRT		269	18	0	48	123	128	107	77	0	134	150	93
CUM RECRT		269	287	287	335	458	586	693	770	770	904	1054	1147

Figure 6.1.b: Sample Corrected Results

Personnel policies implemented for other reasons may also increase the attrition rate. Examples of these type of policies include changes in the length of contract extensions, the length of enlistments, mandatory retirement policies, changes in recruit training policies and changes in recruit quality. The MECP model can be used to perform a sensitivity analysis with respect to a particular policy. For example, the CG may be able to determine that a change in contract extensions would only affect the attrition of E-4 through E-6 personnel. The MECP model allows the user to examine the impact of changes in attrition rates in those paygrades on the entire force structure.

Unlike the above discussion of increased attrition rates, the possibility of decreased attrition rates is unpredictable. Changes in policy such as the Selective Reenlistment Bonus program, the quality of recruits accepted and quality of life programs seek to decrease attrition rates. However, as discussed in Chapter III, it is difficult to quantify the human decision making process to leave the service. The MECP model can also be used to explore the possible effects of these kind of policy changes.

2. Promotions

Changes to the promotion rates will affect both the forecast force structure and the accession needs.

a. Paygrades E-5 through E-9

The MECP model utilizes the PYR_i and $PCT_i(t)$ parameters to estimate the E-5 through E-9 promotion rates. These parameters relate to CG personnel policy and can be changed to directly reflect a changing force structure. The spreadsheet model allows explicit changes to these variables.

b. Paygrade E-4

Promotions to paygrade E-4 are a direct reflection of the CG A-school (formal training required to advance to E-4) policy. The estimates used by the model are a four year average and we have determined that this provides the best available estimate. However, it is clear that much more accurate results can be obtained by using the results of the A-school model as input to the MECP model's E-4 promotion rates. Conversely, by varying the E-4 promotion rates in the MECP model, we can forecast the number of A-school graduates that will be needed to obtain any desired level of E-4s in any month.

c. Paygrade E-1 through E-3

Promotions to paygrade E-3 are estimated from a four year average of promotions. In Chapter II, we discussed the fact that this historic data was missing and we were obliged to compute the "data" using the balance of flow equation. It is recommended that as more data becomes available, these promotion rates be updated using standard estimation techniques. It appears that the best

interpretation of the results, with the estimates we have, is to view the stocks in paygrades E-1 through E-3 aggregated into one category. This is how the CG currently views these paygrades. The MECP model, however, is set up to provide a paygrade breakdown for the time when more accurate data becomes available.

3. Growth Pattern

In Chapter IV we described our assumptions of near linear change between the beginning of year force strength and the end of year force strength. The CG may want to change this assumption for many reasons.

a. Payroll costs would be minimized by encouraging growth to occur at the end of the year or shrinkage to occur at the beginning of the year. This situation might occur if the CG was required to give a mandatory pay raise to its personnel, but was not provided the funds to do so.

b. The CG normally has a long range schedule of unit commissionings and decommissionings, major facility changes and personnel needs. It may be desirable for the growth pattern to approximate the anticipated personnel needs.

c. Historically typical FTEs lie in a range near the average of N(0) and N(12). The relative size of that range depends on the difference between N(0) and N(12). When the difference is small, the FTE range can include

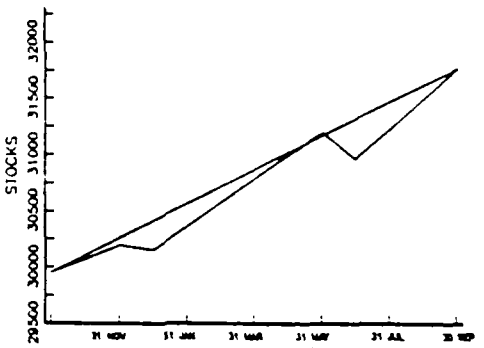
N(0) and N(12). A large difference, however, typically results in a FTE range close to the average. A FTE constraint which is outside the typical range might result in month to month changes in force strength that would be unacceptable.

d. The recruiting needs forecast by the MECP model may be unattainable by the recruiters or they may exceed the capacity of the recruit training center.

Any of these situations can be dealt with by changing the FTE constraint and/or the multiplier A. The model is extremely sensitive to FTE. Major changes in this constraint, especially outside the previously described typical range, will cause large fluctuations in the monthly stocks. Since the FTE constraint and multiplier A are highly correlated, it will be necessary to experiment with various combinations to obtain the desired results. Figure 6.2 is an example of the growth patterns resulting from making several changes to the FTE or multiplier A. In Figure 6.2.a, we see the default solution for a beginning strength of 29953,an ending strength of 31775, an FTE of 30740 and model's default multiplier A equal to 1.535. In Figure 6.2.b we see the solution resulting from increasing the FTE to 31550.

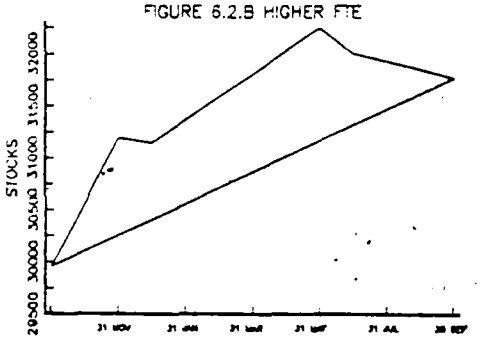
In Figure 6.2.c we see the solution resulting from decreasing the FTE to 30250. In Figure 6.2.d. we see the solution resulting form increasing the multiplier A to 1.9. In Figure 6.2.e we see the solution resulting from decreasing

FIGURE 6.2.A DEFAULT



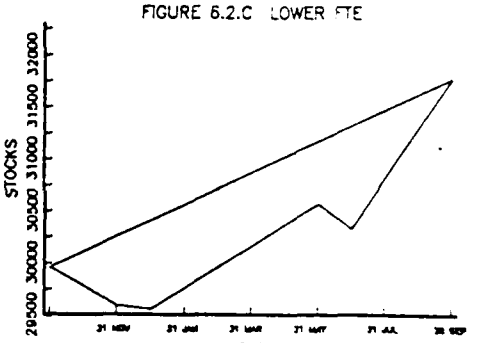
START=29953 END=31775 FTE=30740 A=1.535

FIGURE 6.2.B HIGHER FTE



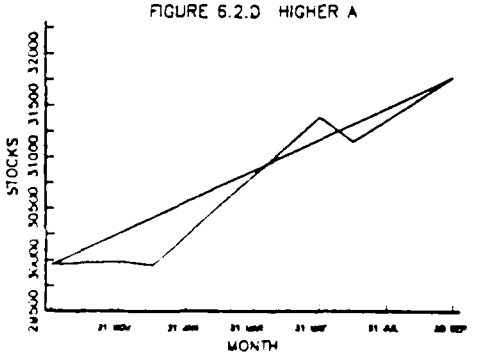
START=29953 END=31775 FTE=31550

FIGURE 6.2.C LOWER FTE



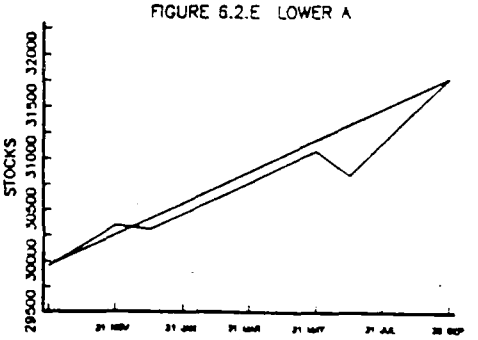
START=29953 END=31775 FTE=30250

FIGURE 6.2.D HIGHER A



START=29953 END=31775 FTE=30740 A=1.9

FIGURE 6.2.E LOWER A



START=29953 END=31775 FTE=30740 A=1.0

Figure 6.2: Growth Pattern Examples

TABLE 6.1: RECRUIT FORECASTS

	Original	FTE=31550	FTE=30250	A = 1.9	A =1.0
OCT	696	1195	394	592	773
NOV	499	998	196	395	576
DEC	200	200	200	200	200
JAN	619	631	613	701	557
FEB	729	775	698	804	673
MAR	707	744	681	767	661
APR	706	736	685	770	657
MAY	701	733	680	769	649
JUN	100	100	100	100	100
JUL	845	522	1040	786	891
AUG	928	597	1129	870	972
SEP	793	578	989	745	835
TOT	7523	7809	7405	7499	7544

the multiplier A to 1.0. The impact of each of these cases on recruit forecasts, as taken from the recruit forecast line of the spreadsheet output, is summarized in Table 4.1.

Occasionally, the CG may wish to ignore the FTE constraint altogether. An FTE equal to the average of the beginning and ending stock will result in a growth pattern that is as close to linear as possible. Alternatively, the results of Chapter IV can be ignored all together.

In Chapter IV, we assumed that we would ignore the FTE constraint in the partial year case, after 1 June. Our previous assumptions state that once the 31 MAY stock is known, the 30 June stock, N(9), can be estimated directly because the attrition rate and recruit numbers are fixed. It is possible to meet the FTE constraint exactly in a partial year model where k = 8 or 9 and by specifying any combination of N(10) and N(11) which satisfies the equation:

$$FTE_9 = [N(9) + N(12) + 2*N(10) + 2*N(11)] \div 24$$

In the case where k = 10 the exact FTE is met for the value of N(11) which satisfies:

$$FTE_{10} = [N(10) + N(12) + 2*N(11)] \div 24$$

In summary, it may not be possible to generate acceptable solutions and heed all the constraints without making some modifications to the MECP model parameters. The MECP model allows the decision maker to evaluate the effect of relaxing or restricting any combination of the parameters.

VII. SUMMARY AND CONCLUSIONS

A. SUMMARY

In this thesis, the problem of forecasting the enlisted CG monthly accession needs and force structure is solved by using a modified Markov transition model to integrate estimations of the pertinent personnel flows into a comprehensive MECP model.

The monthly attrition rates for each paygrade are estimated with an econometric regression model. The promotion rates to paygrades E-5 through E-9 are estimated through the use of a model which approximates the CG promotion process. Promotions to paygrades E-2 through E-4 are estimated from historic data. The monthly stocks are systematically calculated to meet a man year consumption constraint. Accessions are calculated from the balance of flow equation.

The model is implemented on a spreadsheet and allows the decision maker to examine the possible effects of various policy changes on the model results.

B. VALIDATION OF THE MODEL

The availability of complete data for the first eight months of FY87 (1 OCT - 31 MAY) allowed us to assess the reliability of the MECP model over a short period of time. A statistical comparison is inappropriate because the actual

data reflects numerous changes to policy and goals. We will attempt to show that the MECP model forecast for FY87 favorably compares with the actual data.

1. MECP Model Forecast

The 1987 forecast began with 1 October stocks (see Figure 7.1) and economic data available on 1 October. The major parameters are:

a. Starting stock = 29953

b. Ending stock target = 31775

c. FTE constraint = 30740

The attrition rates were calculated from forecast economic data that was available prior to 1 OCT 86.

The model results initially showed a significant decline in E-4 stocks. As previously discussed in Chapter VI, in a situation of significant growth (5.9 percent in this case) we expect to have to adjust some of the model parameters. We increased the E-4 promotion rate from .04133 to .05. Figure 7.1 is the resulting forecast for FY87 based on data available prior to 1 OCT 86. The actual stocks and recruits for 1 OCT 86 through 31 MAY 87 are listed in Figure 7.2.

2. Comparison of Forecast Results and Actual Stocks.

We can assess the reliability of our forecast by comparing plots of the forecasts and the actual values over time.

	1 OCT	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
E-9	300	301	302	302	304	306	308	310	312	310	312	315	318
E-8	506	493	495	494	498	501	505	508	512	508	512	517	521
E-7	2756	2750	2732	2721	2720	2734	2752	2771	2790	2776	2798	2817	2841
E-6	5410	5376	5351	5330	5292	5251	5287	5323	5359	5329	5242	5411	5458
E-5	5455	5409	5375	5347	5742	5677	5523	5409	5446	5404	5537	5499	5546
E-4	7515	7557	7642	7741	7530	7584	7635	7641	7507	7559	7650	7598	7610
E-3	4286	4237	4219	4243	4130	4150	4149	4176	4225	4286	4137	4187	4165
E-2	2892	2661	2895	3167	3231	3018	3185	3427	3614	3753	3841	3275	3441
E-1	833	1288	1180	807	914	1350	1437	1426	1435	1036	1203	1885	1875
TOT	29953	30072	30191.	30151	30361	30571	30780	30990	31200	30960	31232	31303	31775
FTE		2501.	2510.9	2514.	2521.	2538.	2556.	2573.	2591.	2590.	2591.	2613.	2636.
CUM FTE		2501.	5012.0	7526.	10047	12586	15142	17716	20307	22898	25489	28103	30740
RECRUITS		696	498	200	617	729	704	703	697	100	831	911	769
CUM RECRTS		696	1194	1394	2011	2740	3444	4147	4844	4944	5775	6686	7455

Figure 7.1 MECP FY87 Forecast

	1 OCT	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY
E-9	300	303	304	305	306	307	308	309	309
E-8	506	504	503	498	503	505	505	507	499
E-7	2756	2738	2729	2739	2797	2807	2810	2822	2788
E-6	5410	5442	5432	5485	5518	5567	5544	5511	5473
E-5	5455	5380	5326	5743	5664	5508	5491	5429	5320
E-4	7515	7501	7491	7197	7058	6986	6992	7037	7133
E-3	4286	4338	4478	4351	4591	4712	4716	4878	4899
E-2	2892	3008	3274	3481	3496	3448	3608	3680	3884
E-1	833	949	780	452	636	830	687	705	501
TOT	29953	30163	30317	30251	30569	30670	30661	30878	30806
FTE		2505	2520	2524	2534	2552	2555	2564	2570
CUM FTE		2505	5025	7549	10083	12635	15190	17754	20324
RECRUITS		570	482	204	606	518	646	372	
CUM RECRUITS		570	1052	1256	1862	2380	3026	3398	

Figure 7.2: FY87 Stocks

a. Attrition Rates

The attrition rate forecasts drive most of the other model forecasts and are considered first. In Figure 7.3, we see a good forecast of attrition rates for paygrades E-4 through E-6. The results for paygrades E-8 and E-9 are mixed, however, it should be noted that the largest discrepancy for E9 attritions (OCT 86) translates to an error of four people; likewise, the largest discrepancy for E8 attritions (FEB 87) translates to an error of two people. In paygrade E-7, the estimates are consistently low. However, due to the low attrition rates, underestimation averages less than six people each month (out of a stock of about 2800). The trends for the paygrades E-1 through E-3 look good but paygrades E-2 and E-3 are overestimated, while paygrade E-1 is underestimated. In Figure 7.4, the aggregate attrition rate is consistently underestimated, probably due to the influence of the E-1 paygrade. We suspect that the E-2 and E-3 attrition rates are overestimated due to the method of "computing" the data discussed in Chapter II. We suspect that the E-1 attritions are underestimated due to the adjustment made to account for a recruit training policy change discussed in Chapter II. The problems noted might suggest a need to at least temporarily adjust the model's attrition rates if there is evidence to suggest that the trends noted are consistent with future expectations. Such results are not unusual in econometric regression models and

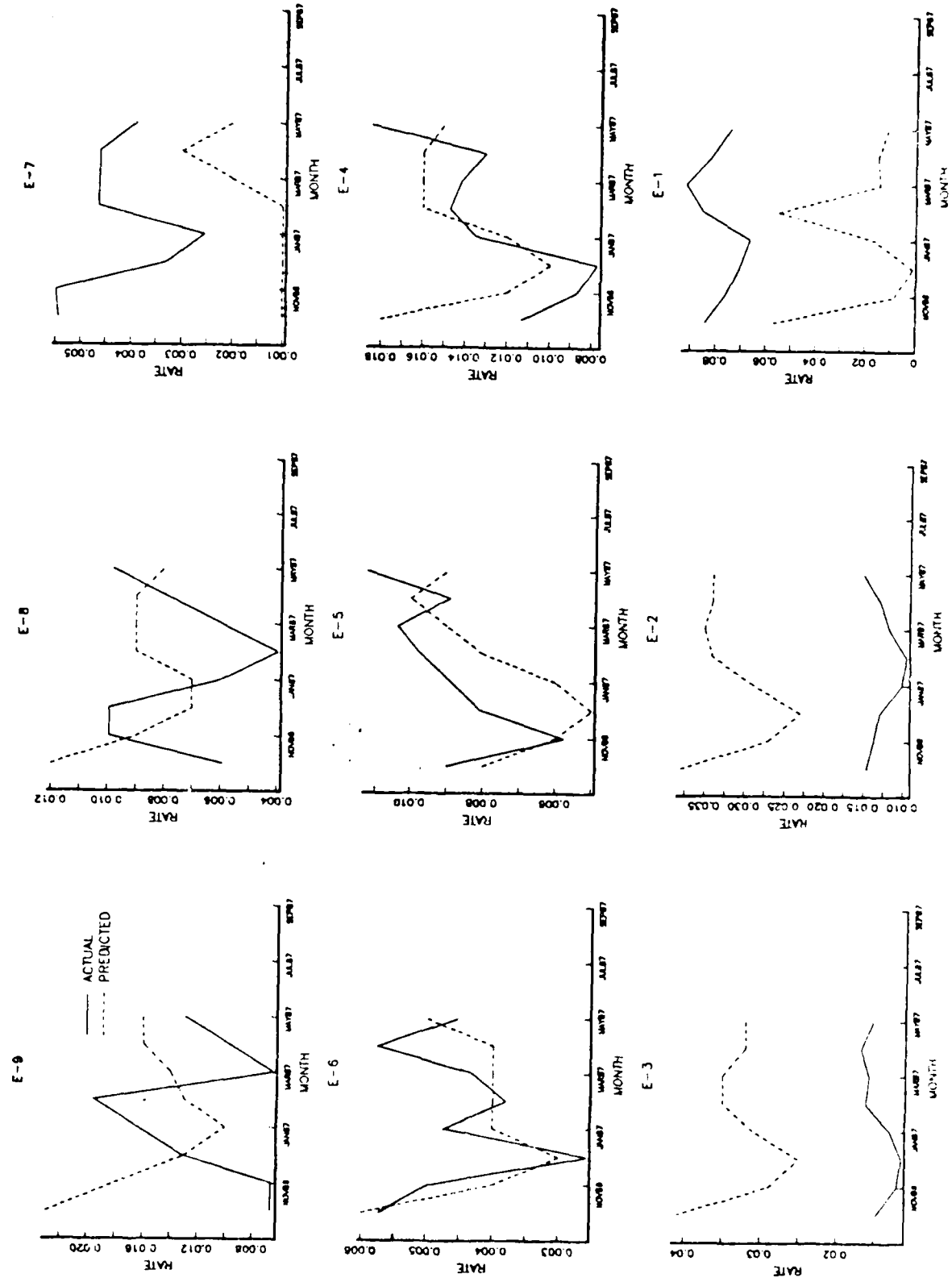


Figure 7.3: Attrition Rates

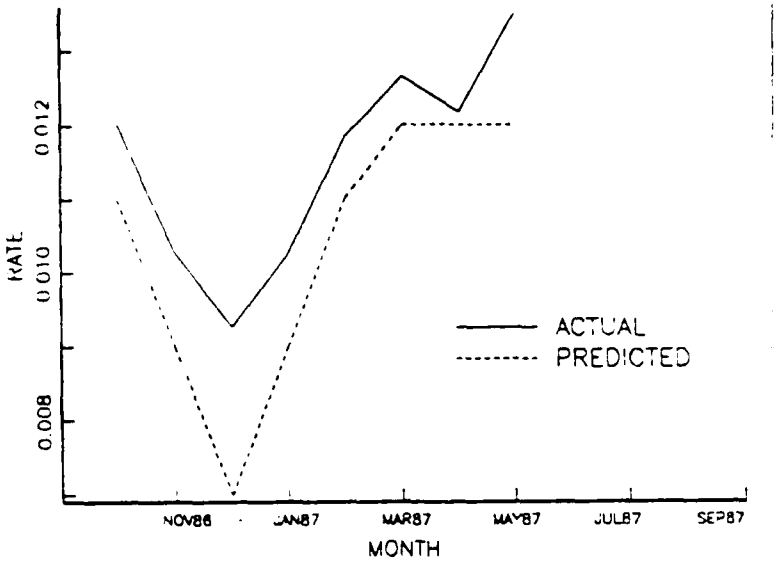


Figure 7.4: Total attrition Rates

emphasize the need to routinely reevaluate the underlying regression model used to forecast the attrition rates.

b. Promotion rates

The MECP model's estimated promotion rates for paygrades E-5 through E-9 are compared to the actual promotion rates in Figure 7.5 (actual data for promotees to paygrades E-2 through E-4 was not available). We see that the most accurate estimate is that of the promotion rate to paygrade E-5. The promotion rates to paygrades E-8 and E-9 are fair estimates except that for some months the forecasts are somewhat high and for others they are somewhat low. The estimates for most of this period seem to be too low for paygrades E-6 and E-7. The underestimation of paygrade E-7 is directly due to the previously mentioned underestimation of the E-7 attrition rates. The underestimation of paygrade

E-6 is not easily explained, however, looking ahead to Figure 7.7 (stocks) we can see a large spike in E-6 stocks, indicating the possibility of an isolated policy change. A careful examination of the data indicates that the 1 OCT, E-6 stock was larger than the historic percentage of total force strength (PYR parameter). The model shut off promotions until the correct pyramid structure was restored. This is normally how the CG operates. For some reason this policy seems to have been temporarily changed, however we are encouraged in that as the year progresses, the actual and forecast stocks seem to be converging.

c. Recruits

Figure 7.6 indicates that the forecast accessions reflected the actual accessions reasonably well. The CG reduced the target end strength from 31775 to 31375 in JAN 87 and since the forecasts were based only on information available prior to 1 OCT 86, we would expect the accession estimates for the months after 31 JAN 87 to be somewhat high, as reflected in Figure 7.6.

d. Stocks

The comparison of stocks seen in Figure 7.7 indicates reasonably good forecasts for paygrades E-7 through E-9 and E-5. The significant difference in paygrade E-6 suggests a change in the billet structure that is not

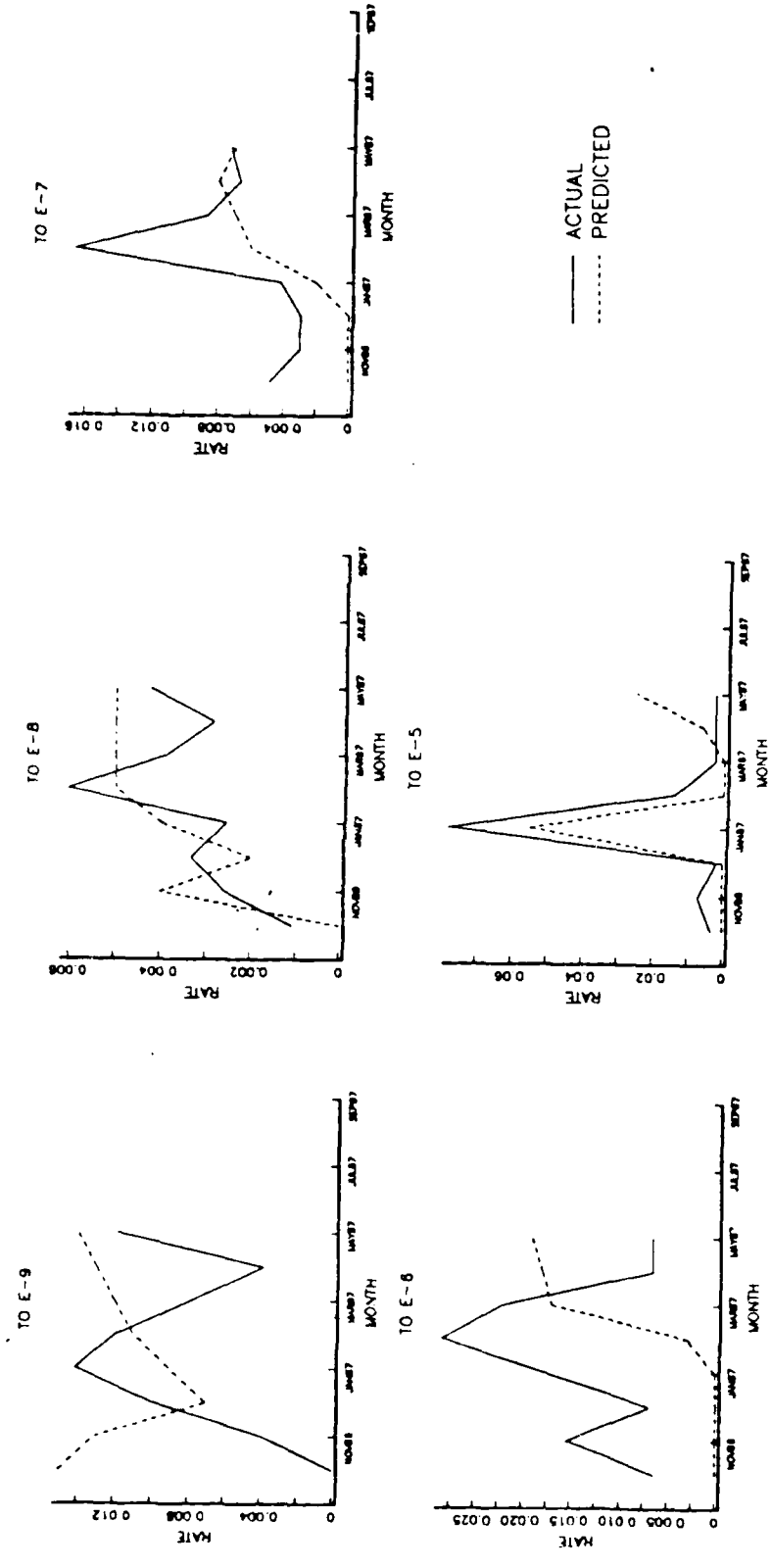


Figure 7.5: Promotion Rates

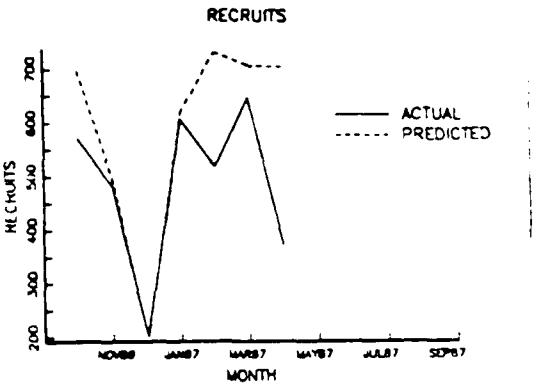


Figure 7.6: Accessions

reflected in the MECP model. The sharp decline in E-4 stocks that is also not reflected by the forecasts is due to the E-4 promotion adjustment, previously mentioned, made to account for the significant growth anticipated in this scenario. In reality, such an adjustment was not made until later in the year as seen by the upturn in actual stocks after MAR 87. This is a good example of how the MECP model can provide input to the A-school model. The increase in the E-4 promotion rate from .041 to .05 suggests that in order to maintain the E-4 stocks in the growth scenario we are examining, it would be necessary for the CG to increase the number of A-school graduates. In summary, the total stock comparison in Figure 7.8 is as favorable as can be expected.

C. CONCLUSIONS AND RECOMMENDATIONS

We conclude that the MECP forecasts seem to reliably reflect the actual data for the eight month period examined. The important discrepancies are explained in terms of parameters included in the MECP model which would have been adjusted in the regular use of the model.

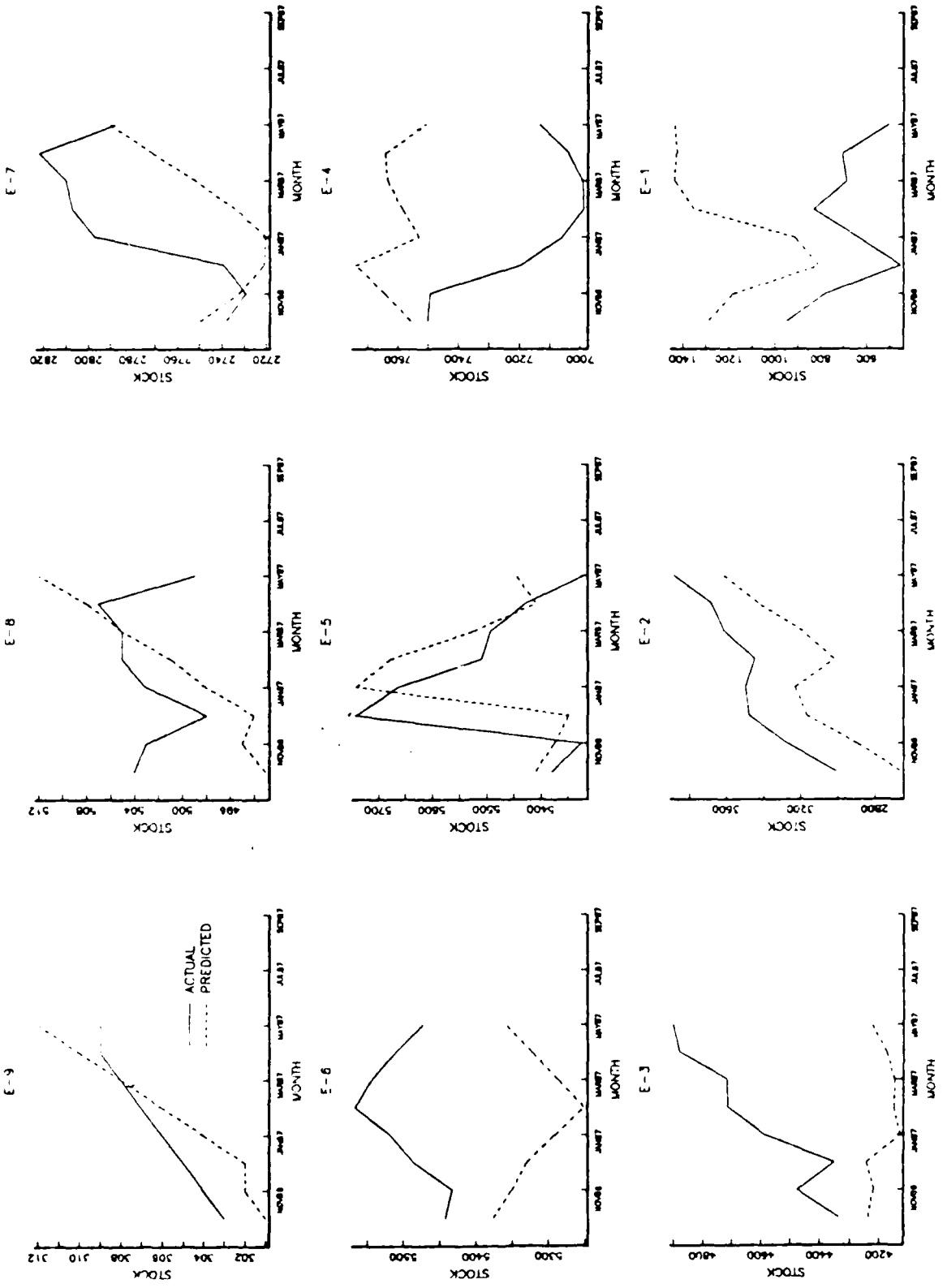


Figure 7.7: Stocks

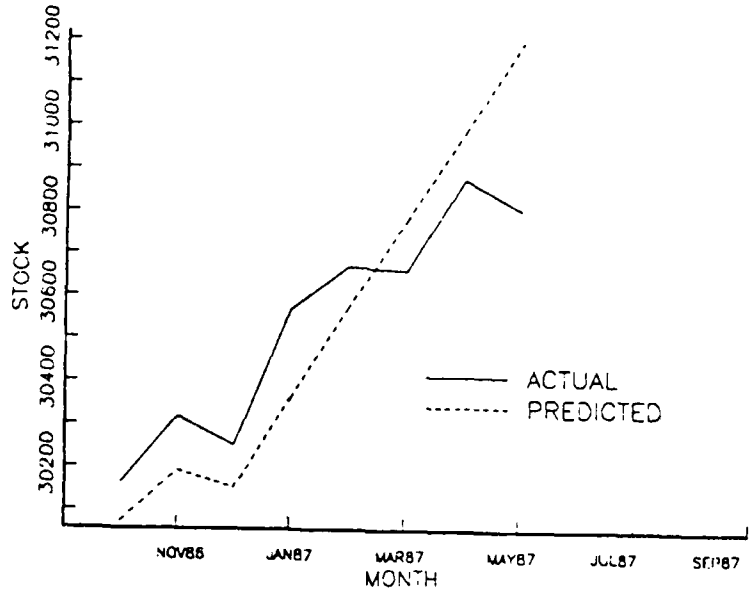


Figure 7.8: Total Stocks

The continued collection of pertinent personnel data, especially as data becomes available during more turbulent economic environments, could provide more accurate estimates of the personnel flows, especia.ly, attrition rates and promotion rates to paygrades E-2 through E-4. Additionally, the model might be modified in the future to allow for the optional specification of fixed recruit levels.

The MECP model seems to provide satisfactory forecasts of monthly accession needs and force structure. Additionally, it has the potential to provide valuable input into other CG personnel models such as the A-school and SRB models. The MECP model is easily modified to reflect changing personnel policies and economic conditions in its forecasts, providing the decision maker with the opportunity to explore the possible effects of a variety of different situations.

APPENDIX A

DATA UTILIZED IN THIS STUDY

Data is modified as described in Chapter II.

ACCESSIONS

Source: Office of Military Recruiting (PMR)

Month	E-6	E-5	E-4	E-3	E-2	E-1	Total	Quota
OCT 80	9	14	9	9	17	542	600	600
NOV 80	6	8	9	6	21	501	551	550
DEC 80	1	23	19	23	6	97	179	131
JAN 81	2	13	10	5	30	678	748	750
FEB 81	9	21	12	11	25	574	652	650
MAR 81	1	9	3	4	19	381	427	425
APR 81	6	22	8	3	18	317	374	375
MAY 81	9	18	3	8	22	314	374	375
JUN 81	4	7	3	4	7	227	252	250
JUL 81	2	8	1	7	10	225	253	250
AUG 81	7	14	2	2	6	237	268	267
SEP 81	0	19	7	8	15	391	450	450
OCT 81	0	19	9	6	18	388	450	450
NOV 81	7	33	9	6	20	376	451	450
DEC 81	5	18	5	14	18	100	160	150
JAN 82	2	7	3	9	5	424	450	450
FEB 82	2	1	1	1	5	441	451	450
MAR 82	0	0	0	0	1	450	451	450
APR 82	0	0	0	0	0	419	419	420
MAY 82	0	0	0	0	0	361	361	360
JUN 82	0	0	0	0	0	220	220	220
JUL 82	0	5	2	7	0	360	374	356
AUG 82	3	3	2	9	5	345	367	356
SEP 82	0	5	3	12	10	332	362	354
OCT 82	2	6	1	8	30	425	472	465
NOV 82	1	0	2	16	28	421	468	465
DEC 82	0	3	1	35	25	313	377	280
JAN 83	3	5	0	34	53	489	584	573
FEB 83	4	15	1	24	57	366	467	436
MAR 83	5	3	4	33	73	413	531	465
APR 83	2	6	2	24	85	452	571	521
MAY 83	3	4	1	31	82	548	669	611
JUN 83	2	4	2	14	59	102	183	101
JUL 83	2	14	5	15	66	483	585	510
AUG 83	3	9	3	11	79	697	802	740
SEP 83	4	14	0	13	67	531	629	580
OCT 83	1	6	0	19	63	487	576	597

Month	E-6	E-5	E-4	E-3	E-2	E-1	Total	Quota
NOV 83	2	4	0	12	63	359	440	476
DEC 83	3	8	2	14	45	130	202	225
JAN 84	1	6	0	2	51	360	420	423
FEB 84	3	4	2	11	48	232	300	300
MAR 84	2	11	2	10	62	287	374	377
APR 84	4	9	1	13	53	351	431	450
MAY 84	3	12	1	16	48	297	377	385
JUN 84	2	7	6	7	36	21	79	12
JUL 84	1	7	6	5	21	332	372	379
AUG 84	1	5	4	3	8	183	204	208
SEP 84	3	4	1	3	10	140	161	165
OCT 84	3	4	11	13	45	391	467	470
NOV 84	3	8	16	15	58	367	467	470
DEC 84	4	16	11	15	36	222	304	290
JAN 85	3	8	25	13	79	417	545	576
FEB 85	4	11	16	24	58	315	428	485
MAR 85	3	25	7	11	68	261	375	485
APR 85	4	19	17	14	52	261	367	483
MAY 85	2	20	23	17	61	237	360	345
JUN 85	0	3	4	1	0	17	25	0
JUL 85	3	18	17	11	42	345	436	400
AUG 85	2	6	15	11	41	360	435	388
SEP 85	2	9	6	12	51	388	468	362
OCT 85	1	16	16	11	54	382	480	485
NOV 85	3	5	4	6	38	222	278	308
DEC 85	0	0	0	0	2	51	53	70
JAN 86	0	0	0	9	7	212	228	225
FEB 86	0	0	0	25	45	270	340	380
MAR 86	0	0	0	11	50	281	342	418
APR 86	0	0	0	9	63	258	330	458
MAY 86	0	0	0	14	51	265	330	466
JUN 86	0	0	0	10	7	87	104	0
JUL 86	0	0	0	26	78	425	529	570
AUG 86	0	0	0	7	8	126	141	206
SEP 86	0	2	0	20	67	527	616	564

STOCKS

Source: COMMSTAT Report

Month	E-9	E-8	E-7	E-6	E-5	E-4	E-3	E-2	E-1
OCT 82	315	474	2630	5014	5086	8125	4410	4111	746
NOV 82	307	462	2596	4999	5038	8143	4509	4111	822
DEC 82	305	470	2618	4984	5020	8095	4597	4117	765
JAN 83	307	463	2618	4975	4983	8126	4701	4299	667
FEB 83	301	462	2601	4975	4941	8132	4868	4295	767
MAR 83	319	491	2653	5105	5234	7470	4890	4325	764
APR 83	324	492	2640	5101	5252	7393	5097	4375	872
MAY 83	328	492	2645	5144	5281	7265	5219	4502	867
JUN 83	324	488	2643	5167	5192	7260	5332	4540	891
JUL 83	319	485	2644	5165	5144	7247	5438	4721	717
AUG 83	317	491	2700	5234	5294	6952	5473	4865	727
SEP 83	317	482	2670	5204	5259	6759	5595	4755	1052
OCT 83	316	503	2647	5159	5214	6701	5699	5004	1131
NOV 83	313	503	2653	5149	5173	6793	5580	5147	1012
DEC 83	313	505	2668	5130	5117	7003	5479	5348	826
JAN 84	314	507	2663	5162	5087	7261	5389	5378	634
FEB 84	319	509	2689	5231	5354	6966	5368	5313	596
MAR 84	318	511	2691	5190	5317	6959	5502	5119	646
APR 84	324	503	2684	5200	5283	7136	5520	4952	658
MAY 84	329	505	2695	5208	5240	7174	5632	4819	657
JUN 84	327	509	2707	5213	5163	7307	5812	4574	728
JUL 84	327	510	2709	5195	5111	7534	5740	4416	434
AUG 84	326	514	2743	5295	5440	7234	5568	4330	447
SEP 84	325	519	2742	5297	5357	7170	5515	4037	526
OCT 84	314	509	2723	5267	5249	7286	5518	3937	346
NOV 84	313	513	2724	5263	5193	7313	5619	3710	524
DEC 84	316	515	2717	5250	5104	7399	5599	3600	636
JAN 85	315	516	2712	5245	5096	7556	5598	3700	513
FEB 85	316	516	2719	5392	5482	7112	5434	3736	606
MAR 85	317	520	2736	5353	5483	7176	5411	3629	734
APR 85	312	522	2726	5351	5475	7393	5273	3723	574
MAY 85	317	524	2719	5344	5455	7475	5272	3696	493
JUN 85	312	521	2731	5342	5404	7740	5120	3676	421
JUL 85	313	510	2724	5340	5303	7831	5037	3548	276
AUG 85	314	513	2751	5444	5646	7772	4676	3455	466
SEP 85	309	508	2750	5399	5660	7820	4665	3352	617
OCT 85	309	509	2754	5369	5590	7884	4642	3310	720
NOV 85	308	512	2786	5359	5530	7988	4602	3317	762
DEC 85	311	511	2758	5363	5488	8156	4516	3362	511
JAN 86	305	506	2753	5344	5468	8258	4484	3390	294
FEB 86	307	504	2749	5395	5596	8066	4407	3296	287
MAR 86	303	509	2761	5392	5596	7994	4415	3138	464
APR 86	300	512	2752	5391	5570	8036	4383	3039	519
MAY 86	298	512	2727	5389	5527	8022	4418	2995	513
JUN 86	311	525	2775	5357	5421	8007	4359	3017	488
JUL 86	301	514	2755	5424	5644	7742	4052	2963	311
AUG 86	301	511	2733	5460	5577	7594	4132	2892	530
SEP 86	306	511	2755	5446	5509	7513	4204	2792	702

BILLETS
Source: COMMSTAT Report

Month	E-9	E-8	E-7	E-6	E-5	E-4	E-3	E-2	E-1
OCT 82	329	485	2644	5489	6618	6346	5382	3179	820
NOV 82	329	485	2647	5492	6615	6346	5379	3179	820
DEC 82	329	488	2650	5511	6565	6355	5388	3186	820
JAN 83	329	488	2650	5520	6656	6362	5385	3182	820
FEB 83	331	491	2667	5582	6948	6407	5410	3203	820
MAR 83	331	491	2670	5588	6939	6413	5403	3204	820
APR 83	331	491	2663	5563	6333	6356	5413	3191	820
MAY 83	328	494	2670	5575	6334	6359	5403	3191	820
JUN 83	328	497	2679	5572	6326	6372	5407	3191	820
JUL 83	328	500	2676	5589	6339	6389	5403	3188	820
AUG 83	327	506	2685	5596	6379	6952	5393	3192	820
SEP 83	325	502	2671	5576	6105	6754	5221	3361	820
OCT 83	325	502	2669	5580	6105	6756	5387	3195	820
NOV 83	319	507	2668	5609	6132	6783	5416	3209	820
DEC 83	317	510	2690	5590	6116	6739	5372	3183	820
JAN 84	313	507	2689	5604	6128	6750	5380	3178	820
FEB 84	320	509	2701	5624	6166	6686	5415	3216	820
MAR 84	320	511	2701	5625	6165	6687	5414	3216	820
APR 84	319	513	2712	5636	6180	6701	5414	3216	820
MAY 84	320	509	2703	5609	6124	6642	5370	3186	820
JUN 84	320	512	2714	5632	6137	6670	5436	3209	820
JUL 84	317	518	2727	5632	6125	6664	5392	3200	820
AUG 84	316	518	2727	5626	6118	6663	5393	3198	820
SEP 84	317	518	2732	5638	6125	6682	5401	3206	820
OCT 84	316	516	2726	5624	6125	6671	5382	3197	820
NOV 84	317	517	2728	5624	6121	6669	5382	3197	820
DEC 84	318	515	2728	5636	6132	6678	5382	3197	820
JAN 85	315	518	2733	5623	6081	6662	5370	3186	820
FEB 85	312	518	2735	5631	6097	6671	5373	3186	820
MAR 85	312	518	2732	5630	6094	6658	5354	3185	820
APR 85	310	519	2738	5632	6110	6678	5376	3190	820
MAY 85	312	512	2728	5609	6096	6631	5316	3135	820
JUN 85	311	509	2756	5603	6070	6562	5935	2459	812
JUL 85	309	509	2758	5587	6062	6560	5935	2459	812
AUG 85	308	504	2737	5584	6057	6549	5923	2446	812
SEP 85	309	507	2763	5612	6098	6578	5948	2449	812
OCT 85	306	503	2736	5583	6065	6511	5863	2406	812
NOV 85	303	503	2730	5573	6070	6508	5852	2402	812
DEC 85	303	502	2727	5564	6069	6511	5840	2399	812
JAN 86	302	502	2763	5547	6041	6451	5837	2402	812
FEB 86	301	507	2759	5550	6041	6463	5822	2392	812
MAR 86	301	507	2754	5532	6025	6444	5806	2382	812
APR 86	302	506	2745	5533	6035	6454	5811	2386	812
MAY 86	302	504	2752	5537	6037	6470	5802	2381	812
JUN 86	302	509	2777	5589	6098	6523	5842	2406	812
JUL 86	301	503	2775	5601	6095	6519	5841	2405	812
AUG 86	302	501	2778	5604	6097	6520	5839	2404	812
SEP 86	300	500	2770	5629	6167	6557	5908	2401	812

RETIREMENTS
Source: PMIS Separations Database (P-1)

Month	E-9	E-8	E-7	E-6	E-5	E-4	E-3	E-2	E-1
OCT 82	9	5	9	8	2	4	1	2	0
NOV 82	12	8	18	7	1	2	1	3	0
DEC 82	6	3	14	4	1	2	2	3	0
JAN 83	0	0	2	0	0	1	0	0	0
FEB 83	6	2	8	1	4	2	1	0	0
MAR 83	0	2	7	4	1	0	0	0	0
APR 83	4	0	7	7	4	4	2	3	0
MAY 83	4	1	11	1	1	4	4	0	0
JUN 83	6	5	14	4	2	2	0	2	0
JUL 83	7	5	17	4	2	2	1	0	0
AUG 83	2	11	8	8	1	3	0	2	0
SEP 83	6	1	7	5	1	4	2	3	0
OCT 83	9	6	15	7	0	0	0	0	0
NOV 83	5	4	9	4	0	0	0	0	0
DEC 83	7	4	11	5	0	0	0	0	0
JAN 84	1	1	8	2	2	2	2	2	2
FEB 84	1	2	7	7	2	1	3	2	0
MAR 84	2	1	8	6	2	2	0	2	0
APR 84	1	2	3	8	1	3	0	2	0
MAY 84	5	4	5	5	1	2	5	1	0
JUN 84	9	1	7	4	0	5	3	1	0
JUL 84	10	8	14	6	1	2	2	0	0
AUG 84	5	7	12	6	2	3	4	1	1
SEP 84	6	9	12	5	0	1	1	1	0
OCT 84	9	7	10	4	4	0	0	1	0
NOV 84	6	5	10	6	3	5	3	2	0
DEC 84	1	4	9	4	4	3	1	3	0
JAN 85	3	2	1	1	1	2	1	0	0
FEB 85	10	7	10	3	3	3	2	0	0
MAR 85	3	4	6	7	2	5	1	4	1
APR 85	3	1	8	3	2	1	4	2	0
MAY 85	6	2	9	4	4	4	1	2	0
JUN 85	7	8	4	5	2	6	2	0	0
JUL 85	1	8	6	12	1	3	5	0	0
AUG 85	6	11	17	4	0	0	2	0	0
SEP 85	9	8	4	9	4	4	4	1	0
OCT 85	2	1	1	2	2	2	6	1	2
NOV 85	9	3	4	3	3	2	2	1	0
DEC 85	1	4	2	6	3	3	3	2	0
JAN 86	5	6	7	3	2	3	1	0	0
FEB 86	6	5	9	10	7	3	2	2	1
MAR 86	5	5	6	6	4	1	3	0	1
APR 86	3	3	12	3	4	2	4	0	0
MAY 86	3	5	11	13	1	1	3	1	0
JUN 86	7	6	12	5	1	1	0	2	0
JUL 86	14	10	23	8	1	3	1	1	0
AUG 86	4	11	15	6	1	2	4	2	1
SEP 86	6	9	15	9	3	2	2	2	0

ADMINISTRATIVE DISCHARGES
Source: PMIS Separations Database

Month	E-9	E-8	E-7	E-6	E-5	E-4	E-3	E-2	E-1
OCT 82	0	0	0	1	3	16	15	18	76
NOV 82	0	0	0	0	1	1	1	0	0
DEC 82	0	0	1	1	0	12	25	22	36
JAN 83	0	0	0	0	0	0	2	1	1
FEB 83	0	0	1	0	6	11	22	30	58
MAR 83	0	0	0	2	2	16	28	33	84
APR 83	0	0	0	1	9	17	28	21	97
MAY 83	0	0	0	2	6	15	32	28	84
JUN 83	0	0	0	0	4	11	24	35	117
JUL 83	0	0	0	1	7	23	36	33	50
AUG 83	0	0	0	0	2	18	30	27	137
SEP 83	0	0	0	1	7	21	33	36	115
OCT 83	0	0	0	0	1	6	16	32	126
NOV 83	0	0	0	0	1	5	13	26	105
DEC 83	0	0	0	0	1	6	15	31	123
JAN 84	0	0	0	0	4	16	40	41	59
FEB 84	0	0	0	1	7	10	20	24	56
MAR 84	0	0	0	0	6	15	32	58	97
APR 84	0	0	2	2	11	16	30	34	92
MAY 84	0	0	1	3	4	20	28	38	119
JUN 84	0	0	0	1	4	18	24	36	78
JUL 84	0	0	0	0	1	10	36	30	53
AUG 84	0	0	0	2	11	21	39	47	81
SEP 84	0	0	1	4	4	22	30	36	70
OCT 84	0	0	0	0	14	17	24	36	72
NOV 84	0	0	1	2	2	26	33	35	99
DEC 84	0	0	1	4	4	12	28	28	93
JAN 85	0	0	1	3	6	24	36	32	70
FEB 85	0	0	0	4	5	19	32	40	64
MAR 85	0	0	0	1	10	18	30	40	56
APR 85	0	0	0	2	6	14	35	40	79
MAY 85	0	0	0	1	4	18	27	61	81
JUN 85	0	0	0	4	7	15	26	35	53
JUL 85	0	1	0	4	7	17	26	33	41
AUG 85	0	1	0	3	5	13	28	29	85
SEP 85	0	1	0	1	5	15	24	27	101
OCT 85	0	0	1	0	9	9	30	37	81
NOV 85	0	0	1	0	4	16	31	40	78
DEC 85	0	0	1	2	8	26	25	34	46
JAN 86	0	0	0	1	7	16	32	35	36
FEB 86	0	0	0	4	8	13	27	39	52
MAR 86	0	0	0	1	9	9	27	31	66
APR 86	0	0	1	4	11	24	21	26	82
MAY 86	0	0	0	3	7	25	23	54	84
JUN 86	0	0	1	4	9	21	34	43	69
JUL 86	0	0	0	2	6	17	26	38	55
AUG 86	0	0	1	3	5	14	16	27	91
SEP 86	0	0	0	2	8	17	27	33	109

LOSSES DUE TO NON-REENLISTMENTS
Source: PMIS Separations Database

Month	E-9	E-8	E-7	E-6	E-5	E-4	E-3	E-2	E-1
OCT 82	0	0	0	4	44	53	23	3	1
NOV 82	0	0	0	13	52	85	54	44	48
DEC 82	0	0	2	4	31	34	16	5	1
JAN 83	0	0	1	0	1	2	1	1	0
FEB 83	0	0	2	8	32	49	24	13	0
MAR 83	0	0	0	9	40	40	28	6	1
APR 83	0	0	0	9	34	69	40	11	0
MAY 83	0	0	0	6	43	48	20	11	1
JUN 83	0	0	1	8	61	92	32	5	0
JUL 83	0	0	0	18	61	113	50	16	0
AUG 83	0	0	2	19	76	140	45	17	2
SEP 83	0	0	2	9	59	148	48	8	1
OCT 83	0	0	1	18	66	122	66	18	7
NOV 83	0	0	2	20	72	133	72	19	7
DEC 83	0	0	1	13	46	85	46	12	5
JAN 84	0	0	0	14	48	108	39	12	0
FEB 84	0	0	1	9	38	101	42	15	0
MAR 84	0	0	1	3	44	78	32	8	0
APR 84	0	0	2	16	39	77	34	3	0
MAY 84	0	0	0	17	49	64	17	4	1
JUN 84	0	0	0	15	31	82	24	11	0
JUL 84	0	0	0	13	61	122	55	7	0
AUG 84	0	0	3	10	72	125	65	13	3
SEP 84	0	0	0	16	60	108	40	8	0
OCT 84	0	0	2	10	54	91	42	7	0
NOV 84	0	0	0	11	53	95	33	7	1
DEC 84	0	0	2	9	22	45	17	5	0
JAN 85	0	0	0	13	50	126	37	14	2
FEB 85	0	0	1	6	49	95	38	15	1
MAR 85	0	0	2	5	32	80	37	8	1
APR 85	0	0	1	17	46	67	29	2	4
MAY 85	0	0	1	13	51	72	31	4	2
JUN 85	0	0	2	15	43	65	27	4	0
JUL 85	0	0	1	16	39	74	16	5	0
AUG 85	0	0	1	21	38	81	37	6	1
SEP 85	1	0	2	16	60	78	28	2	0
OCT 85	0	0	2	18	55	81	44	9	0
NOV 85	0	0	1	14	51	74	42	7	2
DEC 85	0	0	0	11	23	44	17	4	2
JAN 86	0	0	0	17	53	108	47	6	9
FEB 86	0	0	0	12	50	83	36	5	1
MAR 86	0	0	2	12	49	86	47	6	0
APR 86	0	0	2	15	62	101	25	6	0
MAY 86	0	0	1	20	87	146	49	14	1
JUN 86	0	0	1	24	92	128	50	15	0
JUL 86	0	0	2	19	72	132	54	10	1
AUG 86	0	0	1	24	66	92	44	4	2
SEP 86	0	0	2	13	38	66	22	3	3

TOTAL ATTRITIONS

Source: PMIS Separations Database

Month	E-9	E-8	E-7	E-6	E-5	E-4	E-3	E-2	E-1
OCT 82	9	5	9	14	50	76	39	23	77
NOV 82	12	8	18	20	58	91	57	47	48
DEC 82	6	3	17	9	32	49	44	30	37
JAN 83	0	0	3	0	1	3	3	2	1
FEB 83	6	2	11	10	42	63	48	43	58
MAR 83	0	2	7	15	45	58	57	39	85
APR 83	4	0	7	17	49	92	72	36	97
MAY 83	4	2	11	10	50	68	56	49	87
JUN 83	6	6	15	12	68	105	57	42	117
JUL 83	7	5	18	23	72	141	91	50	50
AUG 83	2	11	10	30	79	165	75	48	139
SEP 83	6	1	10	15	70	176	83	47	116
OCT 83	9	6	16	25	67	128	82	50	133
NOV 83	5	4	11	24	73	138	85	45	113
DEC 83	7	4	12	19	47	92	62	43	128
JAN 84	1	1	8	16	57	127	82	56	61
FEB 84	1	2	8	18	47	115	65	42	56
MAR 84	2	2	9	10	52	95	64	68	97
APR 84	1	2	7	27	51	96	64	39	92
MAY 84	5	4	6	28	57	91	51	54	121
JUN 84	9	1	7	20	35	107	51	52	78
JUL 84	10	8	14	19	63	137	94	37	53
AUG 84	5	7	15	18	85	153	108	62	85
SEP 84	6	9	13	26	66	131	72	45	70
OCT 84	9	7	13	14	73	109	67	44	72
NOV 84	6	5	11	19	58	130	70	44	100
DEC 84	1	4	12	17	30	60	46	38	93
JAN 85	3	2	2	17	57	154	75	46	72
FEB 85	10	7	11	13	57	119	72	56	65
MAR 85	3	4	8	14	44	103	69	52	68
APR 85	3	1	9	22	54	82	68	44	83
MAY 85	6	2	10	18	59	95	59	84	83
JUN 85	7	8	6	26	53	87	55	40	53
JUL 85	1	9	8	32	49	96	47	38	41
AUG 85	6	12	18	28	45	96	67	35	86
SEP 85	10	8	6	26	71	98	58	31	101
OCT 85	2	1	4	22	67	97	71	47	83
NOV 85	9	3	6	17	58	94	77	49	80
DEC 85	1	4	3	20	34	74	45	40	48
JAN 86	5	6	7	21	63	128	80	42	45
FEB 86	6	5	9	26	66	101	65	47	54
MAR 86	5	5	8	5	23	13	53	22	67
APR 86	3	3	15	18	45	64	27	24	82
MAY 86	3	5	10	35	84	156	65	82	84
JUN 86	7	6	14	27	95	136	74	59	69
JUL 86	14	10	25	29	79	153	82	50	56
AUG 86	4	11	17	34	73	108	65	33	94
SEP 86	6	9	17	24	50	85	53	39	112

PROMOTIONS FROM PAYGRADE
Source: Enlisted Status Division

Month	E-9	E-8	E-7	E-6	E-5	E-4	E-3	E-2	E-1
OCT 82	0	6	8	31	30	67	156	286	279
NOV 82	0	7	18	34	35	39	80	209	234
DEC 82	0	10	11	40	39	30	109	222	409
JAN 83	0	16	41	82	225	573	582	718	663
FEB 83	0	11	18	40	67	125	0	46	62
MAR 83	0	7	13	20	40	58	35	266	282
APR 83	0	6	7	28	109	171	133	303	381
MAY 83	0	1	1	18	51	10	72	210	215
JUN 83	0	3	4	14	9	7	97	246	410
JUL 83	0	5	14	106	201	463	304	415	543
AUG 83	0	2	13	45	50	52	21	207	66
SEP 83	0	2	22	33	16	11	129	303	532
OCT 83	0	6	16	38	51	88	183	48	131
NOV 83	0	6	9	23	33	0	215	105	246
DEC 83	0	4	8	15	19	2	607	728	845
JAN 84	0	9	13	57	159	446	278	337	277
FEB 84	0	1	8	34	28	37	143	331	131
MAR 84	0	5	4	16	38	55	325	397	236
APR 84	0	6	9	32	67	55	188	351	204
MAY 84	0	6	14	33	64	67	290	505	266
JUN 84	0	7	22	96	99	54	382	354	212
JUL 84	0	9	25	84	206	604	435	352	282
AUG 84	0	2	10	26	44	58	143	195	20
SEP 84	0	2	10	23	29	32	278	350	285
OCT 84	0	4	14	27	30	36	161	316	88
NOV 84	0	7	18	32	39	16	216	251	127
DEC 84	0	1	5	10	14	16	222	252	354
JAN 85	0	8	12	33	186	682	367	265	268
FEB 85	0	6	15	44	30	45	212	237	128
MAR 85	0	0	8	15	20	33	346	266	344
APR 85	0	7	9	16	30	52	199	252	217
MAY 85	0	1	4	24	44	38	375	265	268
JUN 85	0	5	18	77	104	43	217	188	100
JUL 85	0	4	17	63	194	591	611	286	189
AUG 85	0	3	11	37	14	72	201	246	137
SEP 85	0	7	13	26	34	36	192	215	153
OCT 85	0	7	19	52	73	69	254	274	274
NOV 85	0	8	12	12	36	53	311	296	352
DEC 85	0	0	3	4	7	25	201	214	280
JAN 86	0	4	6	8	88	295	231	225	166
FEB 86	0	3	14	36	55	120	149	197	41
MAR 86	0	3	8	15	37	73	213	247	135
APR 86	0	1	10	8	30	69	183	260	185
MAY 86	0	6	9	22	30	33	192	194	249
JUN 86	0	8	26	70	58	41	0	35	35
JUL 86	0	12	24	76	212	541	546	682	583
AUG 86	0	3	13	39	96	140	167	297	222
SEP 86	0	8	17	53	56	54	141	256	328

EXPIRATION OF ENLISTMENTS
Source: PMIS Database

Month	Non-rate	First	Subsequent
OCT 82	64	288	183
NOV 82	64	271	173
DEC 82	36	62	127
JAN 83	106	346	184
FEB 83	62	265	164
MAR 83	57	233	216
APR 83	86	174	121
MAY 83	50	169	154
JUN 83	68	193	115
JUL 83	110	311	163
AUG 83	107	330	145
SEP 83	113	368	138
OCT 83	73	356	243
NOV 83	86	339	158
DEC 83	28	76	124
JAN 84	112	449	200
FEB 84	85	343	192
MAR 84	79	278	189
APR 84	57	256	202
MAY 84	64	224	165
JUN 84	57	266	188
JUL 84	92	438	214
AUG 84	126	380	178
SEP 84	98	356	200
OCT 84	82	315	222
NOV 84	68	333	207
DEC 84	44	118	147
JAN 85	105	422	217
FEB 85	108	327	212
MAR 85	75	278	213
APR 85	68	261	267
MAY 85	105	218	236
JUN 85	71	222	261
JUL 85	54	271	298
AUG 85	69	191	284
SEP 85	92	244	240
OCT 85	79	218	316
NOV 85	80	339	249
DEC 85	19	119	185
JAN 86	89	326	296
FEB 86	82	247	276
MAR 86	87	220	264
APR 86	77	257	324
MAY 86	73	263	304
JUN 86	45	196	336
JUL 86	67	211	389
AUG 86	87	180	325
SEP 86	79	186	328

ECONOMIC DATA

Source: BLS Publications

Month	CPI	GNP	Unemployment Rates			
			Males			Aggregate
			20-25	25 +	16 +	
OCT 81	279.90	3164.00				
NOV 81	280.70	3149.70				
DEC 81	281.50	3135.50				
JAN 82	282.50	3121.90				
FEB 82	283.40	3108.30				
MAR 82	283.10	3094.70				
APR 82	284.30	3100.10	15.0	6.9	9.4	9.0
MAY 82	287.10	3105.50	15.5	6.9	9.5	9.4
JUN 82	290.60	3110.90	15.8	7.5	9.7	9.5
JUL 82	292.20	3112.80	15.9	7.5	10.0	9.5
AUG 82	292.80	3114.70	16.6	7.5	10.2	9.8
SEP 82	293.30	3116.60	17.4	8.2	10.7	9.8
OCT 82	295.50	3111.53	17.4	9.1	10.9	10.1
NOV 82	295.80	3106.47	18.0	9.2	11.1	10.5
DEC 82	292.40	3101.40	17.8	9.4	11.2	10.7
JAN 83	293.10	3129.80	17.6	8.7	10.6	10.5
FEB 83	293.20	3158.20	17.8	9.1	10.8	10.4
MAR 83	293.40	3186.60	16.6	9.0	10.7	10.4
APR 83	295.50	3210.50	17.0	8.9	10.7	10.3
MAY 83	297.10	3234.40	17.6	8.8	10.6	10.2
JUN 83	298.10	3258.30	15.7	8.4	10.0	10.1
JUL 83	299.30	3274.33	15.7	8.1	9.8	10.0
AUG 83	300.30	3290.37	15.9	8.0	9.9	9.5
SEP 83	301.80	3306.40	15.0	8.0	9.6	9.5
OCT 83	302.60	3325.97	14.7	7.4	9.1	9.3
NOV 83	303.10	3345.53	13.8	7.1	8.6	8.8
DEC 83	303.50	3365.10	13.3	6.7	8.3	8.4
JAN 84	305.20	3391.63	13.1	6.6	8.1	8.2
FEB 84	306.60	3418.17	12.1	6.4	7.8	8.0
MAR 84	307.30	3444.70	11.9	6.1	7.7	7.8
APR 84	308.80	3458.83	12.7	6.2	7.7	7.8
MAY 84	309.70	3472.97	11.5	5.9	7.3	7.8
JUN 84	310.70	3487.10	11.4	5.6	7.1	7.5
JUL 84	311.70	3493.87	11.7	5.9	7.5	7.1
AUG 84	313.00	3500.63	12.3	5.7	7.2	7.5
SEP 84	314.50	3507.40	12.2	5.6	7.2	7.5
OCT 84	315.30	3511.73	10.9	5.6	7.1	7.4
NOV 84	315.50	3516.07	11.2	5.6	7.0	7.3
DEC 84	315.50	3520.40	11.5	5.6	7.1	7.1
JAN 85	316.10	3529.27	11.2	5.8	7.2	7.2
FEB 85	317.40	3538.13	11.8	5.6	7.1	7.4
MAR 85	318.80	3547.00	11.7	5.6	7.0	7.3
APR 85	320.10	3553.67	11.3	5.8	7.1	7.3
MAY 85	321.30	3560.33	12.5	5.2	6.9	7.3
JUN 85	322.30	3567.00	11.9	5.8	7.3	7.3
JUL 85	322.80	3579.27	11.7	5.6	7.2	7.3

Month	CPI	GNP	Unemployment Rates			
AUG 85	323.50	3591.53	10.7	5.5	6.8	7.3
SEP 85	324.50	3603.80	11.0	5.5	6.9	7.0
OCT 85	325.50	3609.97	11.1	5.5	7.1	7.1
NOV 85	326.60	3616.13	11.2	5.4	6.9	7.1
DEC 85	327.40	3622.30	10.6	5.4	6.7	7.0
JAN 86	328.40	3633.50	10.3	5.3	6.5	6.9
FEB 86	327.50	3644.70	10.7	5.7	7.0	6.7
MAR 86	326.00	3655.90	11.0	5.7	7.0	7.3
APR 86	325.30	3657.73	11.6	5.5	6.9	7.2
MAY 86	326.30	3659.57	12.2	5.8	7.3	7.1
JUN 86	327.90	3661.40	11.0	5.8	7.1	7.3
JUL 86	328.00	3669.73	11.2	5.8	7.0	7.1
AUG 86	328.60	3678.07	11.3	5.5	6.8	6.9
SEP 86	330.20	3686.40	12.0	5.5	7.1	6.8

APPENDIX B

SAS PROGRAM USED IN THIS STUDY

```
OPTIONS LINESIZE = 80;
DATA PART1;
INPUT E9 E8 E7 E6 E5 E4 E3 E2 E1 EALL;
CARDS;
.0286 .0105 .0034 .0028 .0098 .0093 .0088 .0056 .0670    .008895
.0391 .0173 .0069 .0040 .0115 .0112 .0126 .0114 .0377    .011037
.0197 .0064 .0065 .0018 .0064 .0061 .0096 .0073 .0314    .006910
.0000 .0000 .0011 .0000 .0002 .0004 .0006 .0005 .0015    .000417
.0199 .0043 .0042 .0020 .0085 .0077 .0099 .0100 .0482    .008359
.0000 .0041 .0026 .0029 .0086 .0078 .0117 .0090 .0720    .008896
.0123 .0000 .0027 .0033 .0093 .0124 .0141 .0082 .0722    .010778
.0122 .0041 .0042 .0019 .0095 .0094 .0107 .0109 .0646    .009640
.0185 .0123 .0057 .0023 .0131 .0145 .0107 .0093 .0842    .012124
.0219 .0103 .0068 .0045 .0140 .0195 .0167 .0106 .0446    .013770
.0063 .0224 .0037 .0057 .0149 .0237 .0137 .0099 .1238    .015911
.0189 .0021 .0037 .0029 .0133 .0260 .0148 .0099 .0713    .015050
.0285 .0119 .0060 .0048 .0129 .0191 .0144 .0100 .0760    .014487
.0160 .0080 .0041 .0047 .0141 .0203 .0152 .0087 .0721    .014169
.0224 .0079 .0045 .0037 .0092 .0131 .0113 .0080 .1005    .011393
.0032 .0020 .0030 .0031 .0112 .0175 .0152 .0104 .0615    .011946
.0031 .0039 .0030 .0034 .0088 .0165 .0121 .0079 .0604    .010326
.0063 .0039 .0033 .0019 .0098 .0137 .0116 .0133 .0975    .011317
.0031 .0040 .0026 .0052 .0097 .0135 .0116 .0079 .0897    .010725
.0152 .0079 .0022 .0054 .0109 .0127 .0091 .0112 .1187    .011594
.0275 .0020 .0026 .0038 .0068 .0146 .0088 .0114 .0687    .010266
.0306 .0157 .0052 .0037 .0123 .0182 .0164 .0084 .0783    .013010
.0153 .0136 .0055 .0034 .0156 .0212 .0194 .0143 .1230    .015926
.0185 .0173 .0047 .0049 .0123 .0183 .0131 .0111 .0856    .013116
.0287 .0138 .0048 .0027 .0139 .0150 .0121 .0112 .1329    .012264
.0192 .0097 .0040 .0036 .0112 .0178 .0125 .0119 .1221    .013057
.0032 .0078 .0044 .0032 .0059 .0081 .0082 .0106 .0943    .008607
.0095 .0039 .0007 .0032 .0112 .0204 .0134 .0124 .0897    .012864
.0316 .0136 .0040 .0024 .0104 .0167 .0132 .0150 .0693    .012359
.0095 .0077 .0029 .0026 .0080 .0144 .0128 .0143 .0599    .010874
.0096 .0019 .0033 .0041 .0099 .0111 .0129 .0118 .0941    .010750
.0189 .0038 .0037 .0034 .0108 .0127 .0112 .0227 .1095    .012366
.0224 .0154 .0022 .0049 .0098 .0112 .0107 .0109 .0808    .010107
.0032 .0176 .0029 .0060 .0092 .0123 .0093 .0107 .0942    .009909
.0191 .0234 .0065 .0051 .0080 .0124 .0143 .0101 .1180    .011663
.0324 .0157 .0022 .0048 .0125 .0125 .0124 .0092 .1053    .012001
.0065 .0020 .0015 .0041 .0120 .0123 .0153 .0142 .0750    .011741
.0292 .0059 .0022 .0032 .0105 .0118 .0167 .0148 .0682    .011712
.0032 .0078 .0011 .0037 .0062 .0091 .0100 .0119 .0607    .008135
.0164 .0119 .0025 .0039 .0115 .0155 .0178 .0124 .0986    .012369
.0195 .0099 .0033 .0048 .0118 .0125 .0147 .0143 .1220    .011762
```

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.0165 .0098 .0029 .0009 .0041 .0016 .0120 .0070 .0927    .005790
.0100 .0059 .0055 .0033 .0081 .0080 .0062 .0079 .1021    .008262
.0101 .0098 .0037 .0065 .0152 .0194 .0147 .0274 .1053    .016249
.0225 .0114 .0050 .0050 .0175 .0170 .0170 .0196 .0902    .015268
.0465 .0195 .0091 .0053 .0140 .0198 .0202 .0169 .1158    .016091
.0133 .0215 .0062 .0062 .0131 .0142 .0157 .0114 .1151    .013656
.0196 .0176 .0062 .0044 .0091 .0113 .0126 .0140 .1026    .011938
 ;
DATA PART2;
INPUT MNTH CPI1 CPI6 CPI12 PDIF INLAG1 INLAG2;
M2=MNTH**2;
M3=MNTH**3;
M4=MNTH**4;
CARDS;
  2     .0017    .0360    .0557    .0157  332 360
  3     .0075    .0394    .0538    .0138  425 332
  4     .0010    .0303    .0387   -.0013  421 425
  5    -.0115    .0062    .0375    .0075  313 421
  6     .0024    .0031    .0346   -.0054  489 313
  7     .0003    .0014    .0364   -.0036  366 489
  8     .0007    .0003    .0394   -.0006  413 366
  9     .0072    .0000    .0348    .0048  452 413
 10     .0054    .0044    .0258   -.0142  548 452
 11     .0034    .0195    .0243   -.0157  102 548
 12     .0040    .0212    .0256   -.0144  483 102
  1     .0033    .0242    .0290   -.0010  697 483
  2     .0050    .0286    .0240   -.0160  531 697
  3     .0027    .0240    .0247   -.0153  487 531
  4     .0017    .0202    .0380   -.0020  359 487
  5     .0013    .0181    .0413    .0113  130 359
  6     .0056    .0197    .0457    .0057  360 130
  7     .0046    .0210    .0474    .0074  232 360
  8     .0023    .0182    .0450    .0050  287 232
  9     .0049    .0205    .0424    .0124  351 287
 10     .0029    .0218    .0423    .0023  297 351
 11     .0032    .0237    .0414    .0014   21 297
 12     .0032    .0213    .0423    .0023  332  21
  1     .0042    .0209    .0421    .0121  183 332
  2     .0048    .0234    .0420    .0020  140 183
  3     .0025    .0210    .0409    .0009  391 140
  4     .0006    .0187    .0395   -.0005  367 391
  5     .0000    .0154    .0357    .0057  222 367
  6     .0019    .0141    .0352   -.0048  417 222
  7     .0041    .0141    .0374   -.0026  315 417
  8     .0044    .0137    .0366   -.0034  261 315
  9     .0041    .0152    .0375    .0075  261 261
 10     .0037    .0184    .0373   -.0027  237 261
 11     .0031    .0216    .0356   -.0044   17 237
 12     .0016    .0212    .0335   -.0065  345  17
  1     .0022    .0192    .0318    .0018  360 345
  2     .0031    .0179    .0324   -.0076  388 360
  3     .0031    .0169    .0352   -.0048  382 388
```

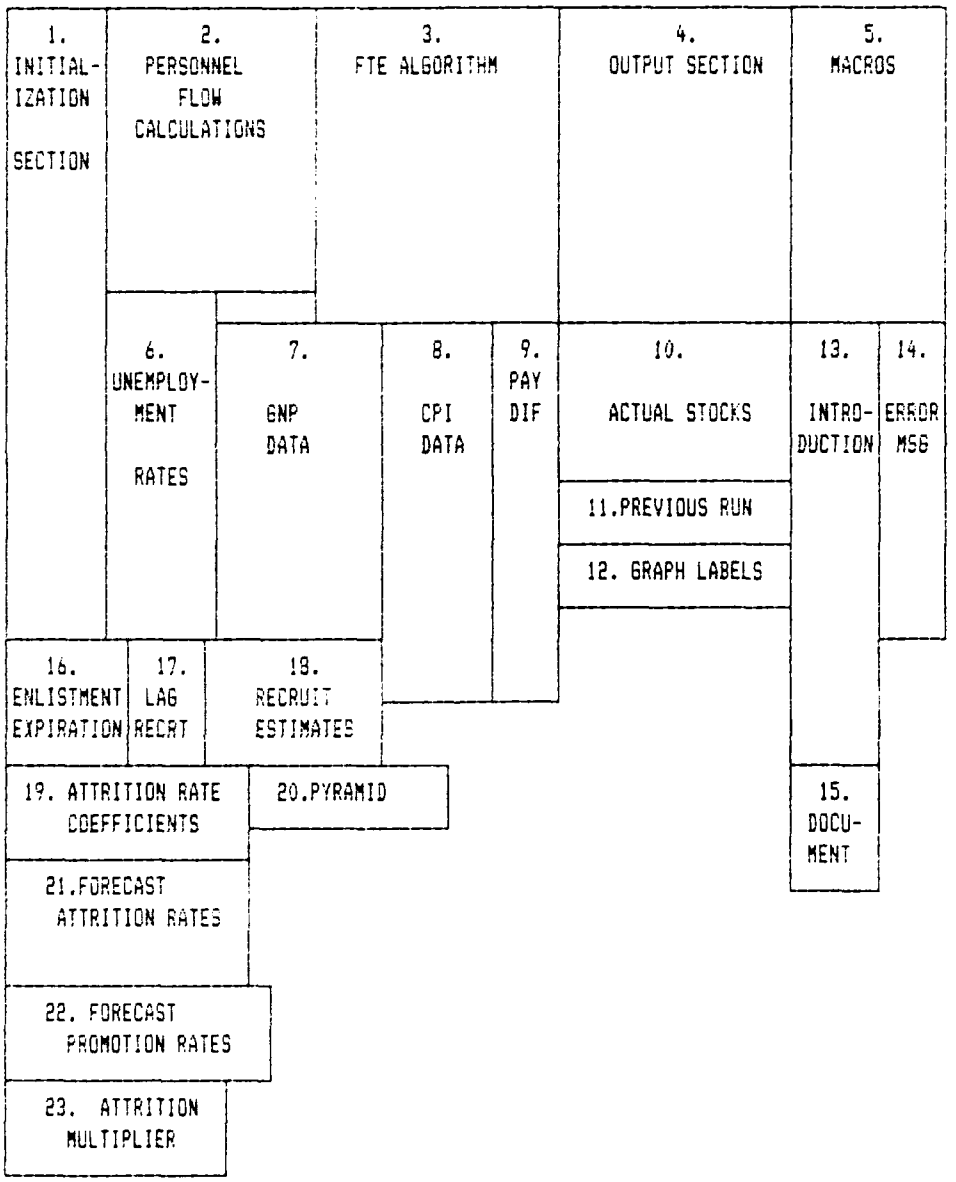
```
  4      .0034    .0165    .0377   -.0023   222 382
  5      .0024    .0158    .0389    .0089    51 222
  6      .0031    .0173    .0318   -.0082   212  51
  7     -.0027    .0124    .0226   -.0174   270 212
  8     -.0046    .0046    .0162   -.0238   281 270
  9     -.0021   -.0006    .0156   -.0144   258 281
 10      .0031   -.0009    .0174   -.0226   265 258
 11      .0049    .0015    .0161   -.0239    87 265
 12      .0003   -.0012    .0158   -.0242   425  87
  1      .0018    .0034    .0176   -.0124   126 425
;
DATA PART3;
 INPUT GNP1 GNP6 GNP12 EESUB EE1ST EENR EMPLAG E20LAG E25LAG ETOTLAG;
 EETOT=EENR+EE1ST+EESUB;
CARDS;
  .0006    .0071   -.0166   183   288    64   .12222   .10828   .24242   .17582
 -.0016    .0037   -.0137   173   271    64   .11702   .16000   .31884   .15957
 -.0016    .0003   -.0109   127    62    36   .12632   .16129   .33333   .16842
 -.0016   -.0031    .0025   184   346   106   .10526   .12658   .25333   .15464
  .0092    .0055    .0161   164   265    62   .06122   .10692   .16000   .06000
  .0091    .0140    .0297   216   233    57   .06122   .07229   .21333   .05882
  .0090    .0225    .0356   121   174    86   .01980  -.04598   .09756   .00000
  .0075    .0318    .0415   154   169    50  -.02857  -.02299  -.02198  -.01835
  .0074    .0412    .0474   115   193    68  -.05607  -.02222  -.04348  -.04505
  .0074    .0506    .0519   163   311   110  -.04762  -.11798  -.10638  -.10714
  .0049    .0462    .0564   145   330   107  -.08654  -.10795  -.06897  -.07547
  .0049    .0418    .0609   138   368   113  -.08654  -.10674  -.12088  -.08333
  .0049    .0376    .0689   243   356    73  -.09709  -.09639  -.11111  -.10280
  .0059    .0360    .0770   158   339    86  -.13725  -.13529  -.16854  -.14953
  .0059    .0344    .0850   124    76    28  -.16832  -.21591  -.19318  -.18868
  .0058    .0328    .0837   200   449   112  -.18000  -.15287  -.20238  -.17000
  .0079    .0358    .0823   192   343    85  -.15789  -.16561  -.18519  -.17347
  .0078    .0388    .0810   189   278    79  -.17895  -.23899  -.20000  -.21212
  .0078    .0418    .0774   202   256    57  -.16129  -.20667  -.23750  -.19792
  .0041    .0399    .0738   165   224    64  -.11364  -.13605  -.16216  -.15385
  .0041    .0381    .0702   188   266    57  -.10714  -.16667  -.16901  -.15116
  .0041    .0363     0670   214   438    92  -.13415  -.14286  -.16418  -.14458
  .0019    .0301    .0639   178   380   126  -.06250  -.10687  -.10606  -.07407
  .0019    .0241    .0608   200   356    98  -.03846   .01653  -.10938  -.07692
  .0019    .0182    .0559   222   315    82  -.05128   .02521  -.08197  -.06494
  .0012    .0153    .0510   207   333    68  -.06410  -.14173  -.09677  -.07792
  .0012    .0124    .0462   147   118    44  -.05333  -.02609  -.05085  -.04110
  .0012    .0095    .0406   217   422   105   .01408   .00877   .00000   .00000
  .0025    .0101    .0351   212   327   108  -.01333  -.04274  -.01695  -.04000
  .0025    .0107    .0297   213   278    75  -.02667  -.04065  -.01754  -.01389
  .0025    .0113    .0274   267   261    68  -.01351  -.04098   .00000  -.02778
  .0019    .0119    .0252   236   218   105   .00000   .03670   .03571   .00000
  .0019    .0126    .0229   261   222    71   .02817   .11607  -.07143  -.01429
  .0019    .0132    .0244   298   271    54   .01389   .03478   .03571   .02817
  .0034    .0142    .0260   284   191    69  -.01351   .04464  -.03448   .00000
  .0034    .0151    .0275   240   244    92  -.04110  -.09322  -.01786  -.04225
  .0034    .0160    .0280   316   218    79  -.02740  -.05983  -.01786  -.01429
```

```
   .0017    .0158    .0285    249   339    80  -.02740  -.01770 -.05172  .00000
   .0017    .0157    .0289    185   119    19  -.04110  -.10400  .03846  .00000
   .0017    .0155    .0295    296   326    89  -.05479  -.10924 -.06897 -.08219
   .0031    .0152    .0301    276   247    82  -.08219  -.11966 -.05357 -.09722
   .0031    .0148    .0307    264   220    87   .04286   .00000  .03636  .02941
   .0031    .0145    .0293    324   257    77   .01408   .00000  .03636  .01449
   .0005    .0132    .0279    304   263    73   .00000   .0450?  .00000 -.02817
   .0005    .0120    .0265    336   196    45   .04286   .08929  .07407  .05797
   .0005    .0108    .0253    389   211    67   .02899   .03774  .07407  .05970
   .0023    .0100    .0241    325   180    87   .02985   .08738  .09434  .07692
   .0023    .0092    .0229    328   186    79  -.06849   .05607 -.03509 -.02857
;
DATA DATAALL;
MERGE PART1 PART2 PART3 ;
PROC REG DATA=DATAALL;
MODEL E? ES E7 E6 =   MNTH M2 M3 M4 PDIF CPI1 GNP6 EESUB EMPLAG
  SS2 P R COLLIN INFLUENCE DW;
MODEL E5 = MNTH M2 M3 M4 PDIF CPI1 GNP6 EESUB EE1ST EMPLAG
  SS2 P R COLLIN INFLUENCE DW;
MODEL E4= MNTH M2 M3 M4 PDIF CPI1 GNP6  EE1ST EMPLAG
/ SS2 P R COLLIN INFLUENCE DW;
MODEL E3 E2 =MNTH M2 M3 M4 PDIF CPI1 GNP6 EENR EMPLAG
/ SS2 P R COLLIN INFLUENCE DW;
MODEL E1 E1A=MNTH M2 M3 M4 PDIF CPI1 GNP6 EENR EMPLAG INLAG1 INLAG2
/ SS2 P R COLLIN INFLUENCE DW;
MODEL EALL=MNTH M2 M3 M4 PDIF CPI1 GNP6 EETOT EMPLAG
/;
```

APPENDIX C

MECP SPREADSHEET LAYOUT

Figure C-1 is a diagram of the different modules of the MECP spreadsheet.



SPREADSHEET LAYOUT
FIGURE C-1

The remainder of this Appendix consists of Figures C-2 through C-10, describing each of the sections shown in Figure C-1. Each figure description contains the upper left and lower right spreadsheet cell locations, respectively.

TODAY IS	11-Jul-87
CURRENT	STOCKS
PAY GRADE	COUNT
E-9	314
E-8	515
E-7	2806
E-6	5389
E-5	5476
E-4	7141
E-3	4394
E-2	3922
E-1	1418
TOTAL	31375
MODEL CONSTRAINTS	
DESIRED END STRENGTH	31400
FTE GOAL	31385
CURRENT MONTH NUMBER	0
1 OCT=0 31 OCT=1 30 NOV=2	
31 DEC=3 31 JAN=4 28 FEB=5	
31 MAR=6 30 APR=7 31 MAY=8	
30 JUN=9 31 JUL=10 31 AUG=11	
DECEMBER RECRUITS	200
JUNE RECRUITS	100
MULTIPLIER NEW	0
DEFAULT	25.774462
FISCAL YEAR	1988
E-4 - E-9 OPEN	
RATING LIST: YES =1	1

SECTION 1 - INITIALIZATION: A1, C59
FIGURE C-2

		PROJECTED RESULT FOR FISCAL YEAR 1988											
	1 OCT	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
FY:													
GRADE													
E-9	314	314	315	313	313	314	314	315	315	312	313	313	314
E-8	515	515	516	513	514	515	516	516	517	512	513	514	515
E-7	2806	2810	2814	2797	2907	2806	2811	2816	2821	2800	2804	2808	2808
E-6	5389	5398	5406	5387	5444	5403	5400	5409	5418	5392	5324	5384	5394
E-5	5476	5485	5493	5459	5925	5863	5765	5651	5528	5468	5548	5471	5481
E-4	7141	7040	6964	7017	6570	6635	6712	6785	6848	6900	7002	6906	6818
E-3	4394	4329	4291	4290	4145	4156	4165	4175	4185	4188	4161	4137	4134
E-2	3922	4089	4256	4508	4669	4445	4578	4707	4742	4763	4638	4305	4560
E-1	1418	1444	1419	992	943	1246	1176	1117	1170	902	988	1513	1376
STOCKS		OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
TOTAL	31375	31424	31473	31275	31329	31383	31436	31490	31544	31236	31291	31345	31400
FTE		2616.	2620.	2614.	2608.	2613.	2617.	2621.	2626.	2615.	2605.	2609.	2614.
CUM FTE		2616.	5237.	7851.	10460	13073	15691	18313	20939	23555	26160	28770	31385
RECRT		699	629	200	588	617	539	564	625	100	718	761	602
CUM RECRT		699	1328	1528	2116	2733	3272	3836	4461	4561	5279	6040	6642

SECTION 2 PERSONNEL FLOW CALCULATIONS: C1, T33
FIGURE C-3

FTE CALCULATIONS

A. BEGIN MONTH :1 OCT-NOV,1 JUN-SEP B. BEGIN: 1 DEC-JUN

			FTE CUM FTE		STOCKS DER	DER x Z1	POINTS DER * PT	DER*COEFF	Z COEFF	SLOPE	2613
DEC RECRT	300	OCT	2617	2617	31424-2.76	-2.763897	31377 -86723.04		1		DEC 31178
		NOV	2621	5237	31474-5.53	-5.527795	31379 -173457.6		1		JAN 33792
JUN RECRT	100	DEC	2615	7852	31276-5.46	-5.457943	31381 -171277.1	-27.28971	1	5	FEB 36406
		JAN	2609	10461	31330-3.37	-3.374610	31383 -105906.5	-13.49844	1	4	MAR 39020
DEC ATT	0.0126363	FEB	2613	13074	31383-1.29	-1.291277	31385 -40527.27	-3.873831	1	3	APR 41634
	1.0127930	MAR	2618	15691	31437 0.79	0.7920560	31388 24860.659	1.5841120	1	2	MAY 44247
JUN ATT	0.0128155	APR	2622	18313	31491 2.88	2.8753893	31390 90257.274	2.3753893	1	1	JUN 43776
	1.0130343	MAY	2626	20939	31544 4.96	4.9587227	31392 155662.57	0	1		JUL 39650
DEL	2.0833333	JUN	2616	23555	31237 4.89	4.8946781	31394 153662.30		1		AUG 35525
		JUL	2605	26161	31291 3.26	3.2631187	31396 102448.33		1		
NUM1	1206389.5	AUG	2610	28771	31346 1.63	1.6315593	31398 51227.565		1		
		SEP	2614	31385	31400		31400		1		
NUM2	34.149939										
DEN	57.705493										
OPTIMUM	25.774462										
OPT	151.79214										
FTE CONSUMED	0										
FTE LEFT	31385										
MULT	25.774462										

SECTION 3 FTE ALGORITHM : T1, AG35
FIGURE C-4

OUTPUT AREA

RUN DATE
11-Jul-87

PROJECTED RESULT FOR FISCAL YEAR 1988

	PAY GRADE	1 OCT	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
END STRENGTH	E-9	314	314	315	313	313	314	314	315	315	312	313	313	314
31400	E-8	515	515	516	513	514	515	516	516	517	512	513	514	515
	E-7	2806	2810	2814	2797	2807	2806	2811	2816	2821	2800	2804	2803	2808
FTE	E-6	5389	5398	5406	5387	5444	5403	5400	5409	5418	5392	5324	5384	5394
31385	E-5	5476	5485	5493	5459	5925	5863	5765	5651	5528	5468	5548	5471	5481
	E-4	7141	7040	6964	7017	6570	6635	6712	6785	6848	6900	7002	6906	6818
MONTH	E-3	4394	4329	4291	4290	4145	4156	4165	4175	4185	4188	4161	4137	4134
0	E-2	3922	4089	4256	4508	4669	4445	4578	4707	4742	4763	4638	4305	4560
	E-1	1418	1444	1419	992	943	1246	1176	1117	1170	902	988	1513	1376
MULTIPLIER														
25.774	TOTAL	31375	31424	31474	31276	31330	31383	31437	31491	31544	31237	31291	31346	31400
REMARKS	FTE		2616.	2620.7	2614.	2608.	2613.	2617.	2621.	2626.	2615.	2605.	2609.	2614.
	CUM FTE		2616.	5237.3	7851.	10460	13073	15691	18313	20939	23555	26160	28770	31385
	RECRT		699	629	200	588	617	539	564	625	100	718	761	602
	CUM RECRT		699	1328	1528	2116	2733	3272	3836	4461	4561	5279	6040	6642

SECTION 4 OUTPUT SECTION: AK1, BB35
FIGURE C-5

Monthly rate			Quarterly rate			6 MO DIFF
MAR	1987	7.2	1 ST	1987	7.2	
APR	1987	6.933				
MAY	1987	6.666				
JUN	1987	6.4	2 ND	1987	6.4	
JUL	1987	6.4				
AUG	1987	6.4				
SEP	1987	6.4	3 RD	1987	6.4	
OCT	1987	6.433				-0.11
NOV	1987	6.466				-0.07
DEC	1987	6.5	4 TH	1987	6.5	-0.03
JAN	1988	6.566				0.015
FEB	1988	6.633				0.026
MAR	1988	6.7	1 ST	1988	6.7	0.036
APR	1988	6.766				0.046
MAY	1988	6.833				0.051
JUN	1988	6.9	2 ND	1988	6.9	0.056
JUL	1988	6.933				0.061
AUG	1988	6.966				0.055
SEP	1988	7	3 RD	1988	7	0.050

SECTION 6 UNEMPLOYMENT RATES : C35, M59
FIGURE C-6

Monthly GNP			Quarterly		GNP	6 MO DIFF %
MAR	1987	3735.	1 ST	1987	3735.2	
APR	1987	3740.				
MAY	1987	3746.				
JUN	1987	3751.	2 ND	1987	3751.8	
JUL	1987	3773.				
AUG	1987	3794.				
SEP	1987	3816.	3 RD	1987	3816.3	
OCT	1987	3830.				0.0217123
NOV	1987	3843.				0.0238794
DEC	1987	3857.	4 TH	1987	3857.58	0.0260401
JAN	1988	3869.				0.0281944
FEB	1988	3881.				0.0255178
MAR	1988	3893.	1 ST	1988	3893.6	0.0228716
APR	1988	3905.				0.0202552
MAY	1988	3917.				0.0197516
JUN	1988	3929.	2 ND	1988	3929.93	0.0192516
JUL	1988	3941.				0.0187552
AUG	1988	3953.				0.0187013
SEP	1988	3966	3 RD	1988	3966	0.0186478

SECTION 7 GNP DATA : M33, W59
FIGURE C-7

	Monthly CPI			Quarterly CPI		1 MONTH DIFF %	12 MONTH DIFF %
SEP	1986	327	3 RD	1986	327		
OCT	1986	327.133					
NOV	1986	327.266					
DEC	1986	327.4	4 TH	1986	327.4		
JAN	1987	330.233					
FEB	1987	333.066					
MAR	1987	335.9	1 ST	1987	335.9		
APR	1987	336.333					
MAY	1987	336.766					
JUN	1987	337.2	2 ND	1987	337.2		
JUL	1987	338.763					
AUG	1987	340.326					
SEP	1987	341.89	3 RD	1987	341.89		
OCT	1987	343.16				0.0045936	0.0455351
NOV	1987	344.43				0.0037146	0.0489912
DEC	1987	345.7	4 TH	1987	345.7	0.0037008	0.0524444
JAN	1988	347.033				0.0036872	0.0558949
FEB	1988	348.366				0.0038569	0.0508731
MAR	1988	349.7	1 ST	1988	349.7	0.0038420	0.0459367
APR	1988	351.046				0.0038273	0.0410836
MAY	1988	352.393				0.0038509	0.0437462
JUN	1988	353.74	2 ND	1988	353.74	0.0038361	0.0464020
JUL	1988	355.06				0.0038214	0.0490510
AUG	1988	356.38				0.0037315	0.0481063
SEP	1988	357.7	3 RD	1988	357.7	0.0037176	0.0471703

SECTION 8 CPI DATA : W35, AF65
FIGURE C-8

	ANNUAL COST OF LIVING PAY RAISE = 3 %	DIFFERENCE VARIABLE
OCT	1987	-0.0155351682
NOV	1987	-0.018991237
DEC	1987	-0.0224444897
JAN	1988	-0.0258949297
FEB	1988	-0.02087312
MAR	1988	-0.0159367494
APR	1988	-0.0110836558
MAY	1988	-0.0137462834
JUN	1988	-0.0164020588
JUL	1988	-0.0190510083
AUG	1988	-0.0181063476
SEP	1988	-0.0171703657

SECTION 9 PAY DIFFERENCE VARIABLE : AF35, AK65
FIGURE C-9

ACTUAL STOCKS

PAY GRADE	1 OCT	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
E-9	314												
E-8	515												
E-7	2806												
E-6	5389												
E-5	5476												
E-4	7141												
E-3	4394												
E-2	3922												
E-1	1418												
RECRUIT	0	0	0	0	0	0	0	0	0	0	0	0	0

SECTION 10 ACTUAL STOCKS : AL35, BB52
FIGURE C-10

TOTAL STOCKS	31375	31397	31419	31222	31255	31288	31322	31355	31388	31083	31122	31161	31200
Previous Run													

SECTION 11 PREVIOUS RUN: AK52, BB56
FIGURE C-11

Welcome to the Military Employment Capability Plan
(MECP) spreadsheet supported by G-PE-4.

The Menu for this spreadsheet can be obtained
by pressing the ALT key and M key simultaneously

Documentation for this spreadsheet can be found
on this disk in a file labeled Manual.txt

This MECP model was developed in conjunction
with a master's thesis written by LT Lance L. BARDO
Comments or bugs are welcome!
This version was last updated JUNE 1987

SECTION 13 INTRODUCTION : BB35, BH78
FIGURE C-12

	NON-RATE	FIRST	SUB
OCT	66	241	365
NOV	72	226	334
DEC	27	212	256
JAN	67	246	364
FEB	51	228	373
MAR	51	230	337
APR	68	254	371
MAY	53	237	394
JUN	15	168	414
JUL	51	233	465
AUG	37	163	466
SEP	39	159	354

SECTION 16 ANTICIPATED ENLISTMENT EXPIRATIONS : A59, G77
FIGURE C-13

	LAGGED		RECRTS
AUG	1987	600
SEP	1987	600

SECTION 17 LAGGED RECRUITS : H59, L77
FIGURE C-14

	RECRUIT ESTIMATES					
	E-6	E-5	E-4	E-3	E-2	E-1
OCT	4	10	6	11	33	635
NOV	4	10	6	11	33	565
DEC	4	10	6	11	22	147
JAN	4	10	6	11	33	524
FEB	4	10	6	11	33	553
MAR	4	10	6	11	33	475
APR	4	10	6	11	33	500
MAY	4	10	6	11	33	561
JUN	4	10	6	11	12	57
JUL	4	10	6	11	33	654
AUG	4	10	6	11	33	697
SEP	4	10	6	11	33	538

SECTION 18 RECRUIT ESTIMATES : L59, W77
FIGURE C-15

	COEFFICIENT	E-9	E-8	E-7	E-6	E-5	E-4	E-3	E-2	E-1	TOTAL
REGRESSION	INTERCEPT	0.010	0.015	0.004	0.001	0.005	0.005	0.003	0.004	0.166	0.008
COEFFICIENTS	MONTH	0.015	-0.00	0.000	0.000	0.000	-0.00	0.002	0.004	-0.01	-0.00
	MONTH**2	-0.00	0.000	-0.00	-0.00	-0.00	0.000	-0.00	-0.00	0.001	-0.00
	MONTH**3	0.000	-0.00	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	MONTH**4	-0.00	0.000	-0.00	-0.00	-0.00	0.000	-0.00	-0.00	-0.00	-0.00
	PAY DIFF.	-0.10	-0.07	-0.07	-0.00	-0.10	-0.12	-0.13	-0.11	-0.58	-0.17
	CPI DIFF1	1.175	0.533	0.178	0.078	0.490	0.559	0.679	0.637	0.630	0.449
	GNP DIFF6	-0.10	-0.16	-0.01	-0.00	0.016	0.035	-0.07	-0.29	-0.44	0.005
	EXP ENL SUB	0.000	0.000	-0.00	0.000	0.000					0.000
	EXP ENL 1ST					0.000	0.000				
	EXP ENL 4Y							0.000	0.000	-0.00	
	UNEMPLOYMENT	0.019	-0.00	0.001	-0.00	0.000	-0.01	-0.01	-0.03	-0.17	-0.00
	RECRUIT L-81									-0.00	
	RECRUIT L-82									-0.00	

SECTION 19 ATTRITION RATE COEFFICIENTS : A77, Q98
FIGURE C-16

PROMOTION CONSTANTS

	P-RMD	PERCENT FILLED	PCT JAN	PCT JUL
E-9	0.01	1.00	1.00	1.00
E-8	0.02	1.00	1.00	1.00
E-7	0.04	1.00	1.00	1.00
E-6	0.13	0.95	0.96	0.90
E-5	1.20	0.89	0.96	0.90

SECTION 20 PROMOTION CONSTANTS: Q77, X84
FIGURE C-17

		CODE										
FORECASTED	OCTOBER	2	0.026	0.013	0.004	0.005	0.013	0.021	0.036	0.032	0.053	0.015
ATTRITION	NOVEMBER	3	0.023	0.011	0.004	0.004	0.012	0.018	0.033	0.023	0.040	0.014
RATE	DECEMBER	4	0.019	0.009	0.005	0.003	0.012	0.016	0.028	0.021	0.024	0.012
	JANUARY	5	0.017	0.008	0.004	0.004	0.012	0.018	0.035	0.026	0.015	0.013
	FEBRUARY	6	0.015	0.007	0.004	0.004	0.012	0.017	0.034	0.027	0.060	0.012
	MARCH	7	0.015	0.007	0.004	0.003	0.011	0.016	0.031	0.026	0.017	0.012
	APRIL	8	0.017	0.007	0.003	0.004	0.011	0.016	0.033	0.029	0.012	0.012
	MAY	9	0.021	0.009	0.004	0.004	0.012	0.017	0.035	0.033	0.024	0.012
	JUNE	10	0.025	0.012	0.004	0.005	0.012	0.019	0.037	0.035	0.029	0.012
	JULY	11	0.026	0.017	0.005	0.006	0.014	0.022	0.041	0.037	0.015	0.014
	AUGUST	12	0.021	0.024	0.005	0.006	0.013	0.023	0.042	0.033	0.000	0.014
	SEPTEMBER	1	0.027	0.014	0.005	0.004	0.012	0.019	0.032	0.026	0.027	0.013

SECTION 21 FORECAST ATTRITION RATES : A99, Q112
FIGURE C-18

		OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
PROMOTION	E-2	0.016	0.015	0.007	0.011	0.011	0.010	0.012	0.014	0.010	0.018	0.013	0.018
RATE TO:	E-3	0.005	0.005	0.001	0.003	0.003	0.003	0.003	0.004	0.002	0.006	0.007	0.005
	E-4	0.006	0.006	0.000	0.006	0.003	0.004	0.004	0.005	0	0.007	0.006	0.006
	E-5	0.012	0.011	0	0.020	0	0.006	0.009	0.011	0	0	0.023	0.012
	E-6	0.019	0.018	0.003	0.090	0	0	0	0	0	0.021	0.016	0.020
	E-7	0.041	0.041	0.041	0.072	0.041	0.041	0.041	0.041	0.041	0.093	0.041	0.041
	E-8	0.067	0.067	0.067	0.067	0.067	0.067	0.067	0.067	0.067	0.110	0.067	0.067
	E-9	0.371	0.365	0.430	0.556	0.198	0.415	0.460	0.425	0.424	0.608	0.103	0.414
		OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP

SECTION 22 FORECAST PROMOTION RATES : A112, R131
FIGURE C-19

	ATTRITION MULTIPLIER									
	E-9	E-8	E-7	E-6	E-5	E-4	E-3	E-2	E-1	TOTAL
OCT	1	1	1	1	1	1	1	1	1	1
NOV	1	1	1	1	1	1	1	1	1	1
DEC	1	1	1	1	1	1	1	1	1	1
JAN	1	1	1	1	1	1	1	1	1	1
FEB	1	1	1	1	1	1	1	1	1	1
MAR	1	1	1	1	1	1	1	1	1	1
APR	1	1	1	1	1	1	1	1	1	1
MAY	1	1	1	1	1	1	1	1	1	1
JUN	1	1	1	1	1	1	1	1	1	1
JUL	1	1	1	1	1	1	1	1	1	1
AUG	1	1	1	1	1	1	1	1	1	1
SEP	1	1	1	1	1	1	1	1	1	1

SECTION 22 ATTRITION MULTIPLIER : A131, N147
FIGURE C-20

Note:

1. Sections 5, 12, 14, and 15 were ommitted because their display would not have been informative.

2. Formulas can be listed by printing the ranges indicated and using the LOTUS /ppoocq sequence.

APPENDIX D

USER'S MANUAL

TABLE OF CONTENTS

MILITARY EMPLOYMENT CAPABILITY (MECP)

USER'S MANUAL

The MECP has been programmed with LOTUS 123™, version 2.01. The theoretical and mathematical underpinnings of the model are described in detail in the text of this thesis. The actual spreadsheet layout is described in Appendix C. The purpose of this manual is to give instructions on the use of the spreadsheet.

This manual is written for the user who will want to see the effect of major policy changes and for the advanced user who may want to explore many of the more subtle interactions involved.

The instructions that follow assume that the user has a basic familiarity with his/her computer, DOS and LOTUS. This spreadsheet is fully menu driven and once loaded requires minimal knowledge of LOTUS.

A. PRELIMINARIES

1. Prior to using the spreadsheet, it is strongly recommended that a back-up copy of the disk be made. Every attempt has been made to prevent the accidental erasure of formulas and data, however the user may find circumstances when he/she may want to alter data temporarily without losing the original forever. The user familiar with LOTUS may want to read paragraph 4 and skip to section B.

2. Enter the LOTUS environment.

3. Load the spreadsheet named MECP.

4. You will be taken immediately to an introductory section. To obtain the menu, press the ALT key and M key simultaneously.

5. This menu works exactly the same way as the regular LOTUS menus. Use the left or right cursor keys to highlight the various options. On the second line you will see either a brief description of the action obtained when that option is selected, or the sub-menu of additional choices available under that option. Press the RETURN key to select the highlighted item. Alternatively, you can select the option by typing the first letter of the desired menu item.

6. After each action performed, you are returned to the normal LOTUS environment (READY appears in the mode indicator in the upper right hand corner). Press ALT-M to return to the main menu.

7. Anytime you are working your way down the menu tree, you can return to the main level by pressing the ESC key and then the ALT-M keys.

8. The only cells that are unprotected in this spreadsheet are those that the user should alter. If you accidentally try to enter a value in a protected cell, you will get an error message in the upper right corner of the screen. Press the ESC key and make the correct entry.

9. Error messages will usually be displayed in the upper

right hand corner of the screen in the mode indicator block. This block will normally display "READY" if it is waiting for the next command or "WAIT" if the spreadsheet is calculating. Any other message can usually be cleared by pressing the ESC or *RETURN* key. *The user should not be* concerned about the "CIRC" reference that appears at the bottom of the screen, the recursive nature of the model causes the circular references and is appropriately handled in the way the spreadsheet is recalculated.

B. MANDATORY ENTRIES

This section summarizes the entries that must be made for a run to ensure reliable results. A detailed explanation of the menu options is contained in sections C and D.

1. Initial Full Year Run

The following menu options must be utilized in the following order to use the spreadsheet for the first run of the year.

a. The **INPUT** option must be used to initialize all entries in this section. If the current value is to remain unchanged, press the return key. If a change is desired, type the new value and press return. Every time the user presses the return key, the program will automatically move the cursor to the next block to be changed. It is recommended that the user leave the Multiplier New cell equal to zero or blank and the December and June recruit entries should be left at the default values of 200 and 100 respectively for

the first run. Current Month Number cell **must** equal zero. **NOTE:** The nature of the formulas requires the beginning stock and ending stock to differ by at least one (1). The user may view the most recent stocks by pressing the Page Up key. These numbers will provide a guideline for reasonable End Strength and FTE entries.

b. The **UPDATE DATA, ANNUAL** Option must be utilized to enter the actual or forecast values for all six subcategories (CPI,GNP,payraise,unemployment,recruits lagged, and enlistment expirations) at the beginning of a fiscal year. It is assumed that the person maintaining the model will entered this data for all other users.

c. The **UPDATE DATA, MONTHLY** Option must be utilized to enter the 1 OCT stocks. This option must also be used for all partial year models to record the actual stocks to date.

2. Subsequent Full Year Runs

Only the INPUT option need be utilized after the ANNUAL data has been entered.

3. Subsequent Partial Year Runs

a. The **UPDATE DATA, MONTHLY** option must be used to enter the most recent end of month data. Make sure you change the CURRENT MONTH NUMBER selection to reflect the last day of the most recent month . This menu item will also update the most recent stocks section in the **INPUT** section and will recalculate the current total stocks.

b. The **INPUT** option may be used to specify a new target end strength and FTE.

c. You may only change the multiplier new cell, B44, when current month number equals 0 or 1. It is recommended that the user leave this as a zero for the first run. It MUST equal zero for runs after 1 DEC.

4. All Runs

a. The **CALCULATE** option is required to recompute the results for the current entries.

b. The **OUTPUT** option is required to view the results in the desired form (screen, printed, graphically).

C. BASIC MENU ITEMS

This section will give a brief description of all the menu choices illustrated in Figure D-1 except the UPDATE DATA and ADVANCED OPTIONS selections. These are discussed in the next section (Advanced Menu Items).

1. **INPUT** Option

Selecting this option will put you in a portion of the spreadsheet that looks like Figure D-2. Instructions for each possible entry are included alongside the figure. The user should be aware that the most realistic FTE values are those values lying between the beginning of year strength and end of year strength. The December and June recruit entries are fixed levels of recruits based on historical data, additionally, they are automatically set to zero when the annual shrinkage exceeds 3500. The Multiplier entries govern

the rate of growth during the year. In short, the Multiplier default entry specifies the slope of the line segment connecting the 31 DEC through 31 MAY stocks as a function of the slope of the line connecting the current

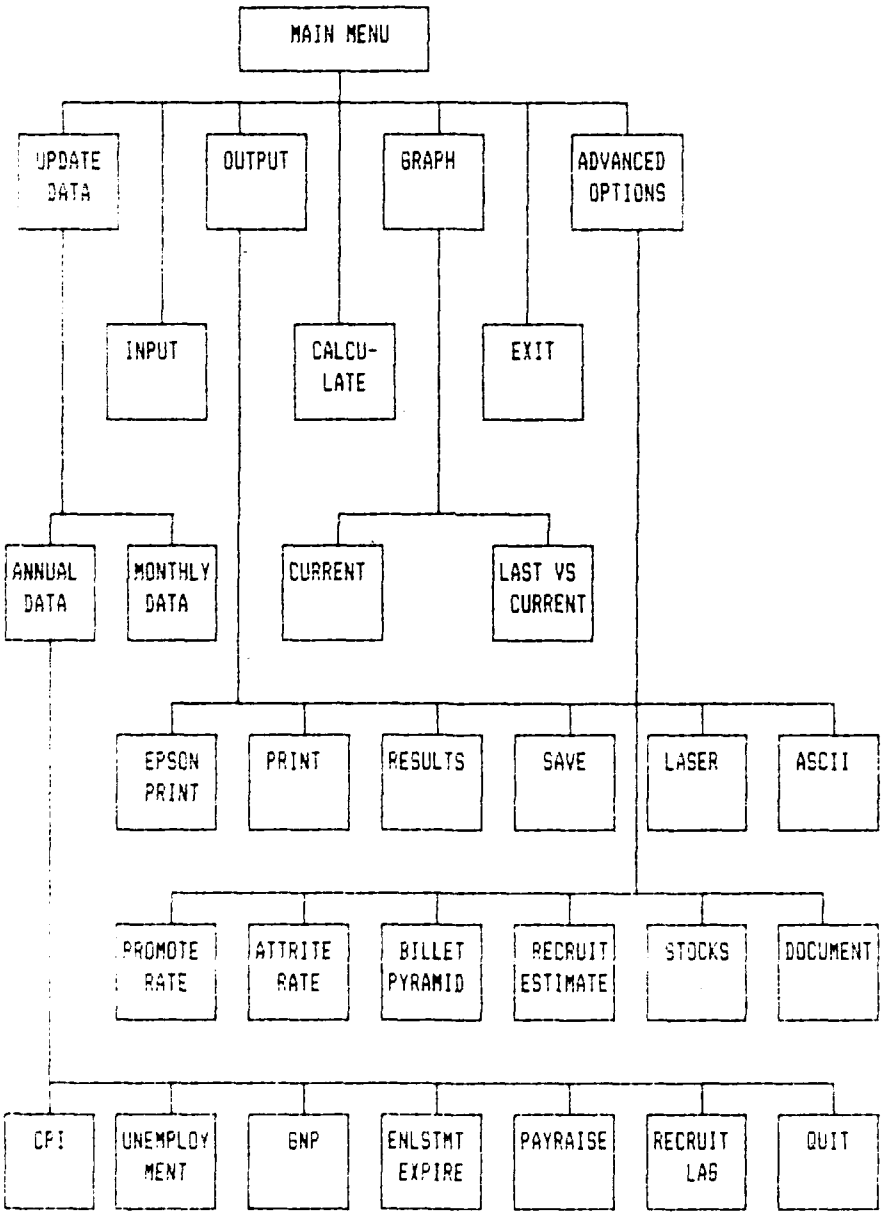


Figure D-1: Spreadsheet Menu Description

stock and target end of year strength. The default value is calculated to minimize the deviation from a line connecting the current stocks and end of year strength. Specifying a Multiplier New, modifies the slope of the 31 DEC - 31 MAY line segment. For example, in figure D-2, the slope of the line connecting the current stocks and the end of year strength is -74.5. The Multiplier default value shown indicates that the optimal slope of the 31 DEC - 31 MAY line segment is -4.82 (shown) times -74.5 (not shown but equal to [29000 - 29894] ÷ 12), or 359.08(not shown). The user is encouraged to experiment with the Multiplier New value to determine its effect on monthly stocks. A more detailed explanation of the Multiplier is found in Chapter IV .

2. **CALCULATE** Option

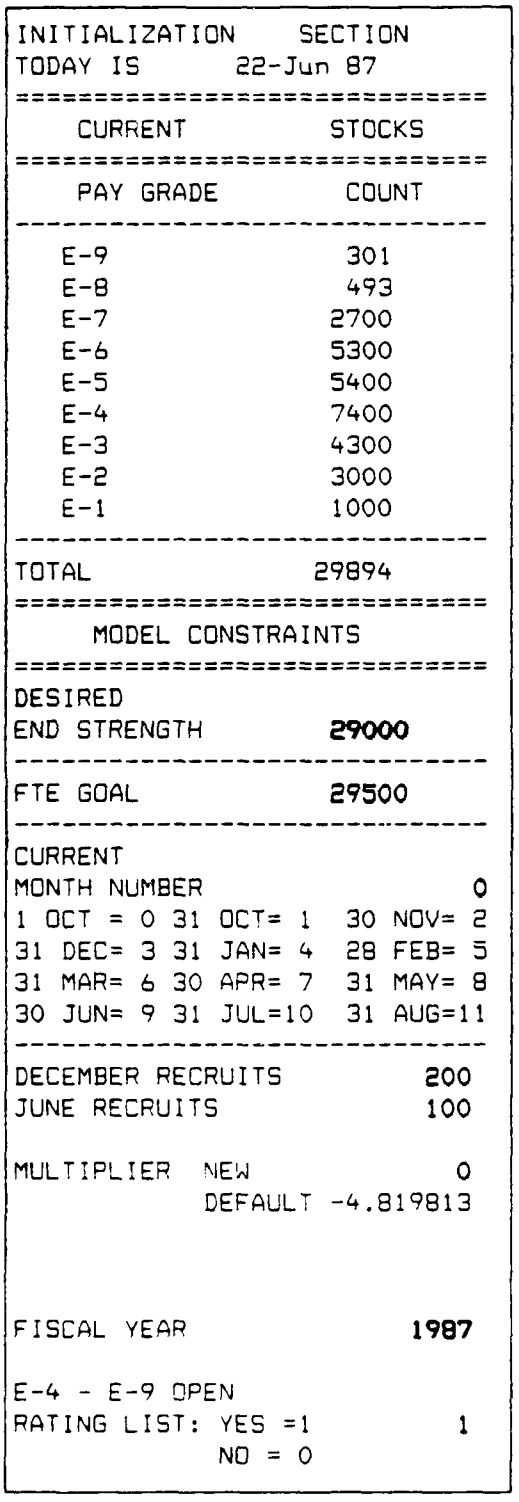
This option recalculates the spreadsheet with the current entries. The value of the total stocks from the previous run is saved for display in the GRAPHICS option. Be sure you want to calculate the current values; the calculation takes approximately 75 seconds on an IBM/XT with a math coprocessor.

3. **OUTPUT** Option

a. **RESULTS** Option (See Figure D-3)

This option allows you to see the results of the current run. Use the cursor keys to scroll right and down to see all the output. The remarks section (cells AL24 - AL34) can be used to briefly document temporary modifications.

Column A Column B



INITIALIZATION SECTION	
TODAY IS	22-Jun 87
CURRENT	STOCKS
PAY GRADE	COUNT
E-9	301
E-8	493
E-7	2700
E-6	5300
E-5	5400
E-4	7400
E-3	4300
E-2	3000
E-1	1000
TOTAL	29894
MODEL CONSTRAINTS	
DESIRED END STRENGTH	**29000**
FTE GOAL	**29500**
CURRENT MONTH NUMBER	0
1 OCT = 0 31 OCT= 1 30 NOV= 2	
31 DEC= 3 31 JAN= 4 28 FEB= 5	
31 MAR= 6 30 APR= 7 31 MAY= 8	
30 JUN= 9 31 JUL=10 31 AUG=11	
DECEMBER RECRUITS	200
JUNE RECRUITS	100
MULTIPLIER NEW	0
DEFAULT	-4.819813
FISCAL YEAR	**1987**
E-4 - E-9 OPEN RATING LIST: YES =1 NO = 0	1

a. Date is entered automatically.

b. All entries are made in column B of the spreadsheet.

c. These are the most recent stocks as entered in the **UPDATE DATA, MONTHLY** option.

d. LOTUS will calculate the total.

e. Enter the desired 30 September stock.

f. Enter the FTE constraint.

g. Enter the month number that corresponds to the stocks entered in (c). Codes are listed.

h. Change these default recruit values if desired.

i. The new multiplier will change the rate of growth. The default value is the optimal value. Change it by entering a number in the NEW cell.

j. Fiscal year being forecast

k. 1 means recruits are being accepted in paygrades E-4 to E-6.

Figure D-2: Initialization

RUN DATE
24-Jun-87

PROJECTED RESULT FOR FISCAL YEAR 1987

	PAY GRADE	1 OCT	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
END STRENGTH:	E-9	300	301	302	302	304	306	308	310	312	310	312	315	318
31775	E-8	506	493	495	494	498	501	505	508	512	508	512	517	521
	E-7	2756	2750	2732	2721	2720	2734	2752	2771	2790	2776	2798	2817	2841
FTE	E-6	5410	5376	5351	5330	5292	5251	5287	5323	5359	5329	5242	5411	5458
30740	E-5	5455	5409	5375	5347	5742	5677	5523	5409	5446	5404	5537	5499	5546
	E-4	7515	7562	7649	7746	7516	7563	7604	7599	7452	7489	7513	7230	7012
MONTH	E-3	4286	4137	4041	3989	3817	3773	3724	3704	3706	3721	3725	3730	3731
0	E-2	2892	2754	3065	3416	3559	3417	3641	3939	4185	4384	4381	4078	4442
	E-1	833	1290	1181	807	913	1349	1437	1428	1438	1040	1212	1907	1906
MULTIPLIER														
1.382	TOTAL	29953	30072	30191.	30151	30361	30571	30780	30990	31200	30960	31232	31503	31775
REMARKS	FTE		2501.	2510.9	2514.	2521.	2538.	2556.	2573.	2591.	2590.	2591.	2613.	2636.
	CUM FTE		2501.	5012.0	7526.	10047	12586	15142	17716	20307	22898	25489	28103	30740
	RECRT		696	498	200	617	728	705	704	699	100	838	926	784
	CUM RECRT		696	1194	1394	2011	2739	3444	4148	4847	4947	5785	6711	7495

Figure D-3: Sample Results

b. **SAVE** Option

(1) **WORKSHEET** Option. The entire worksheet is saved with the name MECPA.WK1. Be sure to rename it if you want to save more than one. Caution: This is a large worksheet! (105K, 60 seconds to save)

(2) **RESULTS** Option. Just the results of the latest run are saved in a worksheet named MECPRSLT.WK1. Be sure to rename it if you want to save more than one.

c. **IBM/EPSON PRINT** Option

The output exceeds 80 characters. In order to print it on a standard width dot matrix printer, the printer must be set to print at the condensed print size (17.1 characters per inch). This option sends the correct command to the Epson and IBM printers. Other printers can be set up using the Print,Options,Setup command in LOTUS (/PPOS\###). Consult your printer manual for the appropriate set-up code to replace ###. This option also clears settings from previous uses.

d. **PRINT** Option

Sends a copy of the latest results to the printer. Prints one table per page.

e. **ERROR MSG** Option

See section F of this manual for a more detailed explanation on how to handle errors.

f. **LASER** Option

Sets up the laser printer for output by turning the page lengthwise.

g. **ASCII** Option

Sends the force structure results to an ASCII file named Output.asc. It is stored in the current directory. If you desire to save more than one set of results in this format, it will be necessary to temporarily exit to DOS, rename the file and return to the spreadsheet. The data is recorded with paygrades as rows (row one is paygrade E-9) and months as columns (column one is 1 OCT stocks).

4. **GRAPH** Option

a. **CURRENT** Option

Displays a line graph of the total stocks for the current run. Press the return key to return to the spreadsheet.

b. **LAST VS CURRENT** Option

Displays a line graph of the total stocks for the current run and the previous run.

5. **EXIT** Option

This option returns the user to the DOS environment. Be sure to make any saves before choosing this option.

D. ADVANCED MENU ITEMS

1. UPDATE DATA Option

a. MONTHLY Option

The actual monthly stocks for each paygrade and the actual recruits up and including the most recent month should be entered here. If actual recruit data is not available, enter zero and the model will use estimated recruits computed as described in Chapter III.

b. ANNUAL Option

This option is used to initialize or update the external data utilized by the model to calculate the attrition rates. It can be updated any time of the year, replacing forecast data with actual data or more recently forecast data. You must use the cursor key to move from cell to cell, do not hit return until the last entry has been made, then hit any cursor key and then the return key.

(1) **CPI Option**. The consumer price index option allows the user to enter actual or forecast CPI (all goods) for the 12 months of the year being forecast and the 12 months of the preceding year in cells Z40 to Z64. Optionally, if data forecasts are only available for the quarter, these values can be entered for the same period in cells AC40 to AC64. Quarterly and monthly figures can be intermixed.

(2) **UNEMPLOYMENT Option**. The total civilian unemployment, age 16+ is entered for the twelve months of the year being forecast and the six months of the preceding year

in cells F40 to F58. Quarterly values can be entered in cells J40 to J58.

(3) **GNP Option**. The gross national product (annual rate) is entered for the twelve months of the year being forecast and the six months of the preceding year in cells P40 to P58. Quarterly values can be entered in cells U40 to U58.

(4) **ENLISTMENT EXPIRATION Option**. The number of enlistment expirations expected for each month of the fiscal year being forecast in the categories non-rate, first enlistments and subsequent reenlistments are entered in cells B65 to B76, E65 to E76, and G65 to G76 respectively.

(5) **PAYRAISE Option**. Any payraise anticipated up to and including 1 JAN of the year being forecast is entered in cell AH42.

(6) **RECRUIT LAG Option**. Enter the number of recruits for AUG and SEP of preceding the year being forecast in cells K64 to K65.

(7) **QUIT Option**. You must use this option to exit this sub-menu. The spreadsheet will also recalculate only the annual data when QUIT is chosen. If no other changes are being made for the run, choose the CALCULATE option from the main menu to obtain results from this new data.

2. ADVANCED OPTIONS

a. **PROMOTION** Option

The user may change the promotion rates for any of the months for paygrades E-3 and E-4. Since these rates are stated as a percentage of the stocks, it is recommended that the default values be used as a reference point for any increases or decreases.

b. **ATTRITION RATE** Option

The values in this section are multipliers of the estimated attrition rates. One (1) implies the estimated (default) attrition rate would be used. A number larger than one (1) would increase the estimated attrition rate. A number less than one (1) would decrease the attrition rate. The multipliers can be changed for any combination of months and paygrades.

c. **BILLET PYRAMID** Option

The values in the column labeled PYRMD describe the number of billets in each paygrade as a fraction of total billets. The values in the columns labeled PERCENT, PCT JAN and PCT JUL describe the fraction of billets in each paygrade that the CG expects to have filled with qualified people . The column labeled PERCENT is for all months except January and July, while the columns labeled JAN and JUL, respectively, are for those months.

d. **RECRUIT ESTIMATE** Option

The estimates for the recruits in each paygrade may be changed. This data is only active if the E-4 - E-9 OPEN RATING cell set in the INPUT option equals one. The user should be aware that manual entries in this section will overwrite the values provided by the formulas. Once new values have been entered, it is necessary to reload the worksheet to get the default values back.

e. **STOCKS** Option

The user may decide to ignore the FTE constraint and enter specific stocks desired during each month. The most likely use of this option would be for the partial year model.

f. **DOCUMENT** Option

This option provides an opportunity for the person maintaining the master copy of the model to document the more permanent adjustments made to the spreadsheet.

E. CONSTRAINTS, INFEASIBILITIES AND POLICY CHANGES

It would be impossible to catalog every problem that might occur when using the MECP worksheet. Chapter VI of this thesis contains a description of various possible policy changes that a user might explore and the resulting interaction of the parameters of the model. The spreadsheet environment was chosen to program this model because of the ease with which numerous changes can be made to a variety of factors. The purpose of this section is to describe some of

the major problems that might occur and their possible resolutions.

1. Recruiting Constraint Violations.

If the model results indicate negative recruits or E-1s for a month, this may imply that the CG cannot shrink the required amount without implementing a policy to increase some of the attrition rates. The user can experiment with the ADVANCED OPTIONS, ATTRITION RATE option to determine how much and which of the attrition rates should be increased.

The model results may also indicate recruits which violate a monthly upper bound of 720. It may be impossible to reasonably meet this upper bound but the user should check the effect of any combination of the following:

a. Increase the December and June recruits using the INPUT option.

b. Decrease the FTE constraint using the INPUT option.

c. Vary the multiplier A (New) using the INPUT option. In a growth situation, increasing the multiplier A may decrease the number of recruits needed toward the beginning of the year. Decreasing the multiplier A may decrease the number of recruits toward the end of the year.

d. Decrease the desired end strength using the INPUT option.

2. Infeasibilities.

Infeasibilities will usually appear as ERR in one or more cells or by the blinking ERROR status in the upper right corner of the screen. Infeasibilities will also be indicated by negative numbers in the results section. Infeasibilities should not occur when operating within historically typical conditions. Briefly stated, typical conditions exist when the beginning stocks and ending stocks differ by less than three percent and the FTE constraint is between the beginning and ending stocks. The user desiring to explore unusual circumstances should refer to Chapter VI of this thesis for a detailed discussion of how the model parameters interact. The next section briefly summarizes the main causes of infeasible results.

F. ERROR MESSAGES

1. Errors, as previously mentioned, will take on one of three forms:

a. ERR will appear in a cell
b. ERROR will appear in the mode indicator (upper right corner of spreadsheet)
c. A negative number will appear in the results.

2. The **OUTPUT, ERROR** option will give you the instructions that appear below to attempt to correct the error.

a. Ensure you have made all the mandatory entries:

(1) Using INPUT option, make sure all required entries are correct (see section D).

(2) The beginning and ending stocks must differ by at least one.

(3) Ensure the external variables have been initialized for the current year (**UPDATE ANNUAL** option).

(4) If the current month is greater than 1, make sure the Multiplier New entry is set to 0.

b. Check the FTE entry. Does it make sense? In the case of a partial year model, is it less than FTE consumed to date? If so, it must be increased for the model to work. Normally you will want FTE to be some number between the beginning of year stock and end of year stock.

c. An error message in the **UPDATE ANNUAL** option will occur if you did not press one of the cursor (arrow) keys followed by the return key after the last entry.

d. Try the **CALCULATE** option once more. It is possible that you changed so many variables that a second iteration of calculations is needed.

e. If the above suggestions have not been helpful in fixing the problem, you should examine the attrition rates, promotion rates and billet pyramid. This will require an understanding of the normal personnel flows that occur in this system. Do the estimated rates make sense in the current scenario?

f. If you still are not able to correct the problem, try reloading the spreadsheet and reentering the desired

values. Failure of the spreadsheet at this point should be brought to the attention of the person maintaining the model.

3. In the case of any error message, it is necessary to press either the ESC or RETURN key to return to the READY mode.

G. TECHNICAL NOTES

The theoretical and analytical methods underpinning the MECP spreadsheet model are discussed in Chapters III through IV of this thesis. Maintenance of the model may require periodic examination of the underlying assumptions and the author would expect a need for changes to the model from time to time.

1. Promotion Rates

There is a possibility that the CG would desire a policy of promoting to E-4 to fill vacancies in the same way as E-5 through E-9 promotions are currently calculated. This can be accomplished by using the LOTUS copy command to copy the formulas in cells F120 through Q120 to cells F121 through Q121. It will also be necessary to modify the formulas. After performing the copy command, the formulas in cells F121 through Q121 will contain the cell reference P64 through P75 respectively. The formula should be edited, replacing P64 through P75 with Q64 through Q75 respectively . Likewise the references to cells J100 through J111 should be replaced with K100 through K111 respectively. It will also be necessary to determine

appropriate PYR (pyramid) for cell T86 and PCT (percent filled) variables for cells U86, V86 and X86. A detailed explanation on determining those variables for paygrades E5 through E9 is contained in Chapter III.

2. Attrition Rates

Temporary changes to the attrition rates can be made using the ADVANCED, ATTRITION option. As mentioned in Chapter III, we anticipate changes to the regression coefficients as more data becomes available. We recommend that as new data becomes available, it should be added to the SAS regression program contained in Appendix B and the analysis described in Chapter III should be reevaluated. A preliminary examination of the raw data should be conducted as described in Chapter II prior to using it in the regression analysis. The new coefficients resulting from updating the regression model can be used to replace the entries in cells F83 through O96.

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